A.D. 1868, 14*th* OCTOBER. N° 3146.

Obtaining and Transmitting Motive Power, &c.

LETTERS PATENT to James Robertson, of the City of Glasgow, in the County of Lanark, North Britain, Engineer, for the Invention of "NEW OR IMPROVED MODES OF OBTAINING AND TRANSMITTING MOTIVE POWER, AND IN THE MEANS, APPARATUS, OR MECHANISM EMPLOYED THEREFOR, PART OF SUCH APPARATUS OR MECHANISM BEING ALSO APPLICABLE TO THE MEASURING OF FLUIDS."

Sealed the 12th January 1869, and dated the 14th October 1868.

PROVISIONAL SPECIFICATION left by the said James Robertson at the Office of the Commissioners of Patents, with his Petition, on the 14th October 1868.

I, JAMES ROBERTSON, of the City of Glasgow, in the County of Lanark, North Britain, Engineer, do hereby declare the nature of the said Invention for "NEW OR IMPROVED MODES OF OBTAINING AND TRANSMITTING MOTIVE POWER, AND IN THE MEANS, APPARATUS, OR MECHANISM EMPLOYED THEREFOR, PART OF SUCH APPARATUS OR MECHANISM BEING ALSO APPLICABLE TO THE MEASURING OF FLUIDS," to be as follows, that is to say:—

This said Invention under the first head or section consists mainly and generally in new or improved modes of generating and heating or producing fluid currents for actuating motive power engines generally.

And under the second head or section this Invention consists in new or improved modes of transmitting motive power to, in, and through or by mechanism or engines constructed so as to have one actuating fluid of each motor introduced, forced, or injected in the form of a jet or stream through an annular nozzle or other conduit made so as to draw another or second fluid or fluids into and through the main duct, or it may be the partially spent currents of the same actuating fluid or fluids which have first passed through the motor as the actuating body, but which have still some force, heat, or other property left which it is or may be desirable and profitable to utilize either alone or along with the said secondary induced fluids, or any desired proportion of these and the partially spent or return currents, and in the directing and applying such combined or compound currents, all so as to actuate the motive power engine or mechanism by the force and expansion of such combined fluid currents (whether liquids as water, or the more elastic gaseous fluids, such as air, steam, or the gaseous products of combustion, are employed separately or jointly) in each or either of these cases, and whether applied to rectilineal, reciprocating, or rotatory classes of mechanical motors or engines, whether the initial or secondary currents are produced in generators of the ordinary construction or by the new or improved modes and means of generating them under the first head or section of this said Invention.

And under the third head or section this said Invention consists mainly in new or improved modes of regulating the flow of the actuating or measured fluids to and from the cylinders of reciprocating motive-power engines, fluid meters, or measuring machines, by forming the ports in and through the working surfaces of the cylinder and piston so as to form also the induction or eduction valve or valves and their fluid-tight working surfaces, and by giving the piston an oscillatory motion on its axis in the well-known and proper sequential time and relative position to suit that of its own longitudinal reciprocatory motion instead of the separate slide and other valves usually employed for the like purposes. The parts of this Invention under all of these heads or sections are susceptible of very many modifications and adaptations to suit the particular fluids and mechanical construction of force-generating and transmitting apparatus or engine and the purposes for which these are to be applied, some modifications only of which it is considered necessary to herein-after and further describe in order to provisionally specify the whole nature of the Invention and the means by

which it is to be carried into effect, all of which improvements forming this said Invention will make motive-power mechanism or engines constructed in accordance therewith more simple both in their construction and action, all so as to be produced and maintained thereafter in action at a less cost or more economically respectively and generally than they have been as heretofore constructed.

This said Invention under the first head or section consists in a mode of generating a current or motive agent of steam, vapour, or gases, so as to actuate motive-power engines by which the water or other fluid to be used or acted upon is for the most part heated by direct contact with the fuel in a state of combustion or with the heated gases eliminated therefrom, instead of by transmitting the heat to the water or fluid through plates, as is done in generating steam in a common boiler. The water or fluid to be heated to be kept from mixing with the fuel by being in a state of motion and by having in the duct or channel for the passage of the fluid to heated, and interposed between it and the heating fuel, a slanting or "louver board" shaped opening or openings or gratings, the direct contact of the water or fluid to be heated taking place mainly at the slanting or "louver board" shaped openings.

One modification or means of generating steam from water under the first head or section of this said Invention consists in the water being entered in a jet, jets, or spray under pressure in an upward vertical direction through an internally conical or trumpet-shaped pipe made of cast iron or any suitable material, having "cored" or formed in it a number of openings slanting upwards in the same direction as the injected water is made to play. The form and size of this conical or tapering pipe may with advantage be such as the water jets would not touch when passing up undisturbed by heat, and may be of any convenient section to fit the position and form these jets assume. Surrounding this conical jet pipe is formed a furnace of about the same height as the jet pipe, having an outer casing of brickwork or other material and one or more firing doors with fire-bars, and openings for the admission of air to support combustion; the furnace thus formed to be covered in at the top and surmounted by a vessel into which the the conical jet pipe is entered and jointed, the same vessel also being provided with a pipe for carrying off the steam or vapour generated. The furnace also to be provided with a chimney for carrying away the smoke and gases, and a damper for regulating the same. Thus formed,

on the furnace being charged with burning fuel and heated to a high temperature, and a jet of water or spray being made to play up through the inverted conical pipe, the heated gases from the fuel in combustion come in contact with the spray in motion, and expands it into vapour, and as it ascends, into steam at a high temperature and in a highly expansive state in swift motion proportional to the initial force or motion of the spray or jets and temperature of the furnace, causing it to enter the pipe or vessel placed in line with and above the current. The slanting or "louver board" annular or segmental shaped openings may be formed with such a direction and degree of slant as to balance the tendency of the spray in motion in a transition state into steam, from flowing into the furnace through the slanted openings, and also the tendency of the heated gases in the furnace from flowing into the inverted conical pipe, or from being induced into the spray or steam, in which case the spray from the water pipe would be converted into steam without admixture of gases from the furnace, or the openings through the conical or trumpet-shaped pipe into the furnace may be so formed as will induce a portion or all the heated air and gases into the spray or steam, forming thereby a highly expansive vapour for actuating motive-power engines generally, in which case no part of the products of combustion would escape, and there would be no necessity for a chimney being formed; the water may be forced into the generator, as described, in jets by the gravitation of an overhead column, or by forcing pumps of any kind, which may have an air vessel attached to make it play continuously, or by a Giffard's injector, or other similar apparatus, and the higher the temperature the water can be forced into the conical heating pipe so much the greater will be the power of the heating pipe or generator to convert the water into vapour. Various modifications can be made of this apparatus as a steam or vapour generator; the form of the jet or jets of fluid or spray may be circular, oblong, or any other in section, and the heating pipe formed accurately, widening out into the form and dimensions the current will assume to preserve the requisite or most economical pressure of steam or vapour, and the "louver board" openings in the sides of the heating duct or pipe or vessel may be formed by adjustible plates. Instead of the furnace being formed as described and the water made to ascend it may be made to descend vertically, or in a horizontal or any other direction to suit circumstances. Instead also of the heating pipe or duct being made sufficiently long to convert the spray into steam the heating process

may be continued by the current being bent round and diverted through two or more straight heating pipes, having their straight portions formed on the same tapering form, and with similar openings for the access of the heating gases from the furnace. For motive-power engines intermittent in their action a reservoir of steam or vapour contained in a vessel jointed to the generating conical pipe would be an advantage, and may be furnished with a self-opening valve opening inwards. The heating fuel may be of anything capable in a convenient way of producing heat, coal, wood, petroleum oil, or common carburetted hydrogen gas; or the apparatus may be used for utilizing the waste gases from iron smelting, puddling, or other furnaces, and the steam or vapour generator may be used for generating steam or vapour to actuate any description of steam engine now in use, as well as to be applied to the description of steam engines to be hereafter described.

This said Invention under the second head or section consists in various modes and arrangements of apparatus for directing the force of steam or vapour from a steam boiler or vapour generator by a jet or jets to actuate the piston or other equivalent moving parts of motive-power engines, and to provide in combination therewith a return channel for the steam or vapour which has passed through the engine back to the eduction or entrance port of the jet or jets of steam from the steam generator, and to connect the return channel for the exhaust steam or vapour to the pipe from the steam boiler or generator, so that that part of it which remains in a state of vapour or spray and not condensed into water by the abstraction of its heat or force by the engine shall be induced by the jet or jets of steam or vapour from the boiler or generator, and by its heat re-expanded and sent through the engine again. The condensed water from the steam in the return channel to be trapped and led into a reservoir or pipe to be sent in a hot state by a pump injector or other means or apparatus back to the steam boiler or vapour generator again to generate steam or vapour for the engine. The steam or vapour or portion thereof having therefore to pass several times through the engine before it is condensed into water, the most suitable form of motive-power engine will be that which will act with a large volume of steam or vapour at a low pressure.

One modification or means of carrying out the improvements under the second head of this Invention consists in the impelled part or mechanical motor which directly receives the force of the vapour being

in the form of an undershot or overshot water wheel enclosed in a case, the axis by preference placed horizontally, having an annular induction port jet piece for the steam or vapour from the boiler connected to the rim of the case near to its top side, and an exhaust port placed about a sixth part of the circumference of the wheel or motor through which "arc channel" the vapour impinges and forces forward the floats or vanes of the wheel or motor until it reaches the exhaust port. The vanes of the rotatory wheel or motor may be curved in a radial direction and formed the full breadth of the wheel, but do not require to fit the case accurately, and the induction and exhaust ports for the better guiding of the vapour to and from the vanes may have "louver board" pieces to direct its course. The exhaust and return channel may be formed in the outer case and be made to serve as a jacket casing for the case of the motor wheel, or be led round underneath the case in a circular form and be connected or led close to the circulating inducing space inside the annular steam jet from the boiler, the lower side of the return channel being provided with a trap opening or openings for the water from the condensed steam leading it to a reservoir or pipe for the supply of the steam generator. On steam being admitted to the annular space it issues through the annular nozzle in a jet and is sent with great force on to the vanes of the motor wheel so as to give it motion, and the exhaust steam or vapour passing round the return channel is induced in along with the steam from the boiler at or in the centre of the induction nozzle and jet, and the condensed water is "trapped" off to or for the supply of the steam or vapour generator. The motion or force communicated to the spindle or axis of the motor or vane wheel can be connected to any kind of gear or moving piece for the utilization of the force.

Various modifications of this description of engine may be made; instead of one induction jet it may have two or more annular or otherwise formed induction jets, and may have these so formed as to give facility for reversing the current of vapour for reversing the motion of the wheel; or the motion may be reversed by a separate wheel fixed on the same axis. The vanes also may be variously curved or shaped, and feathering action may be given to them with advantage. Turbines generally are a very suitable form of engine for being actuated by this mode of return currents of steam or vapour, from the current being allowed to pass through them continuously with only a certain degree

of retardation in giving its force to the mechanical motor or wheel. For example in an inward flow (Thompson's) turbine the annular jet from the boiler can be directed into the motive wheel from its periphery, and on issuing out from its centre so much of its volume as is not expended in force and condensed into hot water be led to the annular induction jet, and passed through the motive wheel again. In a like way the current or jet from the boiler or generator may be directed to the centre first, and form thereby an outward flow turbine, the return current being directed from the periphery of the motive wheel is led to be entered again at the centre. The water from the condensed steam to be "trapped" from the turbine casing in either case for the supply of the boilers as explained. In the same way this mode of utilizing the force of steam may be applied to reaction turbines in the form known as Whitelaw's water wheel, but in all these certain modifications have to be made for the return currents, means of taking off the water from the condensed steam, and for the proportioning the curve and size of vanes to the density, speed, and large volume of vapour in motion to be dealt with. Where great power and and slow angular motion is required in the motive wheel large diameter will be necessary, and in such cases it will be an advantage to have a large cylindrical or conical-shaped motor or wheel with curved vanes fixed on its periphery, and the steam or vapour from the boiler or generator directed along them by a corresponding large annular jet, or number of small jets, and thence at the other end of the motor directed back through another and an inner set of vanes curved in an opposite direction, and as in other modifications so much of the vapour as is not condensed into water to be induced and sent through the first set of vanes and round again. The motion may be reversed when required by setting the current through in a reverse direction, or may be reversed by seperate turbines fixed on the same spindle, and having separate cases, and all necessary details. In like manner this mode of utilizing the force of steam may be applied to vanes, or to a succession of vanes fixed on an axis formed like the vanes of a windmill, and their motion if necessary be reversed by reversing the current. In using steam from a common steam boiler or generator the steam and return steam or vapour before it reaches the motor of the engine or turbine may be superheated and increased in volume in a vessel or tapering channel or pipe, by the pipe being led through the waste heated gases passing from the boiler flues to the chimney, or it may be heated and expanded by direct contact by a "louver board"

opening or openings on the principle of the generator explained under the first head or section of this said Invention, where the gases are induced in among the steam, and for gases not condensible into water a waste pipe would be necessary for their partial escape. In another form all the waste gases and heated air may be induced in along with the steam into the engine or turbine, and after actuating the same returned in a circular channel, having the concave side opens for contact with the atmosphere for the absorption of oxygen or fresh air, and a portion of this heated air or current thus returned sent through the furnace of the boiler to support the combustion of the fuel, and the water from the condensed vapour may be trapped off for the supply of the boiler, and in some cases part of the return gases allowed to escape. Whilst this return mode of utilizing the force of steam or vapour as described can be wrought with advantage by steam or vapour generated in any ordinary steam boiler. It is also intended to apply and use the steam or vapour generator described under the first head or section of this said Invention for generating the vapour to work these return current engines or turbines. Where the generators are adapted to take portion or all of the gases generated in the furnace along with the steam a portion of the vapour can be returned and re-induced in along with the vapour from the generator; or a portion can be sent round a circular channel, with the concave side open to the atmosphere for the purpose of restoring oxygen or fresh air to it by its absorption from the atmosphere for the support of combustion in the furnace, whilst the water from the condensed vapour, gravitating or sent to the bottom of the return channel by its centrifugal force, is trapped off at this point into a pipe or channel to be led or forced to the spray jet for feeding the vapour generator. One injected impellant current and main channel may in this manner, and by these improvements, be made to actuate several engines or motors by separate ducts leading to each from the main. This returned mode of utilizing the force of steam can be applied with advantage to cylinder engines fitted with reciprocating pistons, and in one form by connecting the two induction steam ports of the cylinder, and having formed in them an annular space in the centre or at some intermediate point in these passages, and having a tubular valve piece worked by an eccentric from the crank shaft, or by a "tappet" or other suitable valve motion; the steam to be admitted from the boiler or generator into the annular space in which this tubular valve is placed; this valve is considerably tapered or conical at the ends, fitted accurately

to their respective end seats, and is made slightly shorter than the seat in which it is placed, so that on being moved to one end which requires only a very short traverse it opens a passage for the steam for forcing by an annular jet the piston in one direction, while it establishes an exhausting inducing action to exhaust out the steam or vapour from the exhaust side of the piston, or what of it remains not condensed into water in along with the steam sent by the annular jet into the forcing side of the piston, and vice versa as the motion of the piston and connecting rod and crank goes round. The water from the condensed steam to be "trapped" into pipes or a reservoir in the port passages as the exhaust steam issues, and the steam admitted into the cylinder to be sufficiently small in quantity to allow of the engine abstracting in force such a proportion of heat as will condense it to water. It will be readily understood that many arrangements of slide and other forms of valves commonly in use for steam engines will easily effect this action. Besides being suitable for reciprocating crank engines a useful modification of this mode of utilizing the force of steam in this way will be by long cylinders for working hoists and similar machines with the valve wrought by hand for producing a single traverse of the piston at a time.

Another improvement under the second head or section of this said Invention consists in modes of or mechanism for working wheels and turbines by steam and air combined, or mixtures of steam and gases by direct single currents; the mechanism being similar to the wheels and turbines described in connection with the second head or section of the said Invention, but without the apparatus for causing and regulating the return currents therein referred to. Where the steam is generated by any common form of steam boiler all or portion of the gases produced by the combustion of the fuel can be drawn through the inducing passage of the steam injector, and thereby increase the volume and force of the current, or the injector may be placed to induce in cold air and force or draw all through the boiler furnace, or through a separate heating furnace to mix with and induce the gases eliminated by combustion so as to increase the volume and effective power and driving action of the current to the wheels or turbines, the current may be sent through a second turbine and more cold air induced. It is also intended to use the steam or vapour generator described in the first part of my Invention for generating the motor vapour for transmitting force to these wheels or turbines.

Another improvement under the second head or section of this said Invention consists of a mode of transmitting power to the forms of rotating wheels and turbines described in connection with the second head or section of this said Invention, by exhausting pure or atmospheric air in through these turbines by the exhausting action of inducing injectors, produced by the means and apparatus for generating and directing currents described under the first and second heads or sections of this said Invention. The construction of the motor wheels of the turbines to be similar to those described, but requiring in some cases no casing, the surrounding air by flowing inwards into the turbine causing it to revolve; power may in this way be transmitted to great distances in mines, factories, and warehouses, and at the same time the abstraction of the air by the turbines tend to promote ventilation.

Another mode or means of applying the improvements under the second head or section of this said Invention consists in actuating motive-power engines by heating water and generating steam in a boiler similar to the process of generating steam in an ordinary steam-engine boiler, but instead of the steam being taken or led in pipes to expend and transmit its force to a piston or any impelled equivalent, draw off the water in the boiler to propel or actuate engines, returning the same water again in a continuous stream, and propelling a wheel or turbine as it passes along the pipe from the egress to the ingress openings or orifices in the boiler. The wheels or turbines being similar to those used generally as water-power engines, and somewhat similar to those described in connection with the second head or section of this said Invention. The steam being led off to an ijector on or at the ingress end of the return water pipe at or near the bottom of the boiler to induce and force back the water into the boiler, and by its action in this way to maintain the continuity of the current.

In one modification of a motive-power engine for actuating a mechanical motor analagous to an undershot water wheel enclosed in a case, and to which the water pipes are connected in a suitable way for the impact and egress of the water, a vertical dome-shaped boiler is used having an internal fire-box and funnel at the one side for carrying off the smoke and gases from the furnace in the ordinary way, and it is further fitted with safety valve, water gauges, and pressure gauge, as steam boilers of engines generally are. A water pipe of large dimensions for leading off the water for the turbine is fitted into the top of the boiler descending

down below the water line in the boiler to nearly the top of the fire-box and formed bell-mouthed shaped at the under end, opposite this is another tube of similar dimensions descending down through the fire-box beyond the bottom end of the boiler, at the bottom end of which is fitted a valve opening inwards to the boiler and made self-closing by the pressure of water in the boiler, to this is coupled an annular steam water inducing injector, the central space of the injector for the passage of the water being about the same diameter as the turbine water pipe, the lower end or discharge end or port of the turbine case is coupled to the water inducing connection of the steam injector by a bent pipe, and the central outflow pipe descending from the top of the boiler down below the water line, is coupled by another bent pipe to the turbine, which establishes a continuous course, channel, or circuit for the flow of the water through the turbine. For working the injector a steam pipe is connected to the top of the boiler and the steam branch pipe of the injector, and a starting flow-off pipe and cock is connected to the water return pipe underneath the foot valve and to the annular steam space in the inducing injector; to increase the current by the flow of the water in the boiler an annular shell is placed between the outer shell and the fire-box, so as to make the water flow down through by the outer shell and ascend up by the fire-box end in the direction which the turbine flow pipe current goes, the construction of the boiler being generally such as to favor this action, thus arranged and steam at a high pressure or tension formed in the boiler, let the flow-off cock be opened so as to start the flow through the turbine and clear the injector annular space and pipe of water, which done and the cock suddenly closed, the force of the current in motion through the turbine pipe starts open the foot valve and the water partly reduced in temperature by the abstraction of force in the turbine is again restored by the stream of steam sent into it to nearly its former temperature and forced back into the boiler, and the flow motion of the water maintained through the turbine pipe and turbine, to the axis of which gear of any kind may be connected. In this mode of utilizing the force of steam there will be little loss of water or heat, except what is utilized into force by the turbine or wheel and what passes off in the waste gases of the funnel; similar arrangements for working turbines can be made in connection with Cornish and other forms of boilers.

Another mode or means of applying the improvements under the second head or section of this said Invention consists in mechanism for

transmitting motion to water by a jet or jets of steam or steam injector, and thence to water wheels or turbines, and to pistons or rams for cylinders for such purposes as hoists and lifts.

One modification consists of an endless annular pipe or channel in which is cast at one side and somewhat less in diameter a case to receive a mechanical motor or wheel similar to an undershot water wheel, the annular pipe entering into and out of this case in a circular and unbroken course. Into this course or annular channel the water-wheel formed motor, which is keyed on a spindle and placed in the case in stuffing-box bushes so as to allow the floats or vanes to work in the annular channel, accurate fitting not being necessary. Into this annular channel, at any intermediate point between the induction and eduction ports of the case, is placed an annular steam injector, the central space being about as large as the sectional area of the channel; coupled to this steam injector or steam water lifter is a steam pipe from any ordinary steam boiler and connected also is a cold water supply pipe and a feed pipe from the annular channel to the boiler, as also a waste water pipe carried up above the channel to give pressure of water in the channel. On the annular channel and water wheel case being filled with water, and steam admitted to the injector, the water is set in motion in the annular channel in an endless and return stream, its centrifugal force drawing the water out of the water wheel case all except the water that is caused to course round the channel, and which the floats or vanes of the water wheel dip into, and the motion of the water in the channel impinging on the vanes or floats gives the water wheel motion; the waste water is carried up to such a height as to balance the centrifugal force of the water in motion in the annular channel, and the supply pipe made to admit sufficient water to keep the temperature of the water in the annular case sufficiently cool, a portion of the heated water to be taken away for feeding the boiler, which portion escapes from the annular channel at a high pressure caused by the centrifugal force of the water in the channel. The escape pipe is coupled to the concave side of the annular channel or to the wheel case, and the water escapes with little force; the quantity escaping depending on the amount of heat converted into force from the steam or water. Water wheels and turbines generally may be actuated in this way, but water wheels as described act and apply in the most simple way.

In another modification a steam injector is applied to force in water to a cylinder to give motion to a simple ram like the ram of a Bramah press, and on the water being allowed to flow out of the cylinder the ram by its own gravity or by the action of a weight is caused to return for a fresh stroke. This form of application is chiefly designed for hoists or lifts, the water possessing a facility for regulation which the elasticity of steam does not admit of, and the injector a facility for quick action which is in any other way expensive to accomplish. In another way a small boiler water tank, with feeding gear for the boiler fitted with regulating cocks, would complete the apparatus. The length of lift could be increased by chain and pulley blocks or other equivalent multiplying gear. Instead of a ram a piston may be used in the cylinder, and the injector made to exhaust the water from the one side of the piston and force it into the other. The water tank or cylinder requires a supply of cold water to keep the temperature of the water down, and the hot water can be used for feeding the boiler.

Another mode of carrying out the improvements under the second head of this said Invention consists in mechanism and means for the utilization of the force of air when in process of expansion by heat, and the mechanism and means being similar to some of the apparatus described under the first and second heads of this said Invention. A current of air may be caused to flow up through a conical or trumpet-shaped heater, as described in the first part of this said Invention, for generating steam, and the central flow of air allowed to mix with or be kept separate from the gases issuing from the furnace, and the force of one or both made to actuate wheels or turbines, portion of the heated air to be passed round again in a return current for the support of combustion in the furnace, and may be exposed to the atmosphere in a concave channel open on its concave side to the atmosphere for the heated air to re-absorb oxygen afresh to render the air more fit for the furnace. In these improvements the use of the injector and "louver board" inducing principle or arrangements are adopted for utilizing of the force of steam or vapour in the same way for maintaining the currents in motors, as before described, under the first and second heads of this said Invention.

Another modification or means of carrying out the improvements under the second head of this Invention consists in mechanism for working the condensers of piston reciprocating steam engines in lieu of

the ordinary air pump, and consisting of a condensing vessel, into which the exhaust steam from the engine is made to enter, and a thin stream or jet of cold water made, by preference, to enter in a downward vertical direction, the opening, oblong or broad, in one direction, and thin or narrow in the other, to be regulated by an adjustable valve opening inwards, and loaded by the tension of a strong spring or other equivalent manner. In the bottom of the condensing vessel and opposite to the top valve a corresponding valve is placed opening outwards; this valve, by preference, to be of india-rubber, and of the form known as "Perreaux's valve," and so placed that the jet or stream of cold water entering under pressure and motion will play down through the bottom valve. Underneath the condensing vessel is another shallow vessel to contain a quantity of water around the foot valve to act as a water lute, to keep it air-tight and to form a convenient connection to carry off the condensing water. A double-acting forcing pump or pumps wrought by the engine is provided, and the discharge pipe, from which is connected to the jet valve chest on the condensing vessel, so as to discharge through the jet adjustable valve at every stroke of the engine and pump, an air vessel being provided on the forcing discharge pipe of the pump to make the current in some degree continuous; this pump, if requisite, drawing the water from a well, as well as forcing it into the condenser. Thus arranged, and the engine and pump set in motion, a broad thin stream of cold water is sent with great force into the loaded adjustable valve on the top of the condensing vessel, and down through the condensing vessel out at the foot valve, condensing the steam from the engine, and inducing with it through the foot valve the condensed water and air produced by the condensation of the steam.

Another improved mode, means, and apparatus for condensing the exhaust steam and discharging the condensing and condensed water of reciprocating engines, under the second head of this Invention, consists in using and injecting salt water for condensation, and of retaining a great part of the water condensed from the steam or vapour caused by the contact of the steam and salt water, free or nearly free from salt, to serve for marine engines in lieu of surface condensers. The condenser is similarly constructed and wrought to the modification last described, with the thin broad stream of cold salt water forced down through it, but having a wall piece or guard formed in the bottom of the condenser

above the discharge valve around the course of the injected stream or jet of salt water, and rising up to about a fourth part of the height of the condensing vessel to form a trap reservoir for the fresh water produced by condensation. The exhaust steam from the engine or engines for condensation is admitted in this arrangement at the side of the vessel, which when cylindrical has an annular or other shaped casing all round of a series of plates perforated with small holes in zig-zag position, so as to equalize the force of the steam in process of condensation as it advances and before it reaches the jet of water, and to prevent the current of steam from striking or acting with two great force at any one point upon the stream of cold water. As in partial vacuo the cold water jet in process of being heated will radiate from its surface cold vapour to the steam in passing down through the condensing vessel; the distance and instant of condensation must be an intermediate point between the annular perforated casing described and the surface of the jet of water, and an eddying motion produced from the vapour that proceeds from the cold water, and from the water being in a state of swift motion downwards a downward direction will be given to the vapour in process of condensation, which will fall into the trap reservoir formed in the bottom of the condensing vessel. To facilitate this action a series of plates are fixed, angularly placed and slanting downward and outward close to and all round the jet of salt water, bevelled or slanting like "louver boards," so as to make the cold vapour arising from the water meet with its swift motion the vapour in process of condensation, and further assist the condensed water to settle down in the trap reservoir, whilst the salt water injection stream from the force of its motion plays down through the foot valve; the condensed fresh water being drawn from the reservoir by the feed pump for the engine boiler.

Various modifications can be made of this mode and means of condensation, and the jet of water instead of passing downwards may be forced in any direction, and may be passed over curved plates over the top or sides of the condensing vessel in various ways, to facilitate the condensation and deposition of the condensed fresh water from the salt condensing water.

Another improvement under the second head of this said Invention consists in a mode of applying motive power (such as herein-before described under the first and second parts of this Invention) to or for

the purpose of propelling ships or vessels for locomotion on land, and for the attainment of higher speeds of locomotive engines than has heretofore been attained. For passenger traffic high speed is the chief object, and lightness being essential to this end, a ship or vessel is formed as light as is compatible with the strength necessary, and for the smaller amount of weight to be carried by these improvements. The form of the vessel is to be nearly a parallelogram in beam or cross section with a hollow longitudinally channelled bottom, the length and breadth of beam being great in proportion to the weight to be carried; with two keelsons with the hollow channel between them, one at each side, and the depth small. The bows presenting a very slanting surface and the stern somewhat less so, to the water; when loaded the upper portion of the longitudinal hollow channel referred to to be out of the water, and free for the passage of air between portion of the bottom of the vessel and the water, the sides or parts of the vessel near to and at the outside keilsons being immersed to a considerable depth for buoyancy. The steam boiler, boilers, or generators are fitted into the vessel of great "steaming" or evaporating capacity, but of the lightest construction found suitable. A boiler of the locomotive engine form, or a generator as described in the first part of this said Invention, may be the most suitable and is intended to be used, by preference, placed near the fore part of the vessel, and from which the steam or vapour is conveyed to one or more large steam injectors for inducing air in large quantity in and through them, placed near the bows of the vessel, and down slanting into and entering the air conduit at the "fore" part of the main channel below the centre of the vessel. These steam injectors are preferred to be of the annular form and construction, but other forms of steam jets described in the second head or section of this said Invention may be employed. The inducing ends of the injectors open outward in the direction of the bows of the vessel, and have large conical or bell mouths to receive, induce, and catch the air. Steam being admitted from the generator to the injectors a large volumn of air mixed with steam is forced with considerable speed into and along the hollow channel or course in the bottom of the vessel, interposing between the bottom of the vessel and the water, buoys or relieves the bottom surface from the friction of the water, and the acting currents escaping with great force and volume at the stern of the vessel, propels the vessel forward by its reaction. The keilsons or bottom portions of the sides of the vessel and channel remaining immersed prevents the air and steam current from escaping

at their sides, and a large quantity of cold air is induced into the channel at the bows of the vessel which increases the volume and acting current besides or in addition to what is drawn and forced into it by the injectors, and this air will principally remain near the surface of the water, and the heated air and steam rise and keep more to the upper side of the channel and current. The vessel may be further propelled by additional injectors placed on deck, large area or volumn both of inlet at the bows and discharge at the stern of the vessel being necessary to the success of this improved mode of propulsion. The motion of the vessel may be reversed by having injectors placed and actuated in reverse positions at the opposite end of the vessel. Motion can be given in a similar direct way by steam and air engines to locomotives set on wheels placed on rails and on the ground for the attainment of high speeds.

This Invention under the third head or section consists in improved mechanism and arrangements of the ports of reciprocating cylinder, piston, steam, or fluid power engines, part of which mechanism and arrangements are also suitable for measuring fluids. One principal improvement under this head in its simplest form consists of a cylinder and piston fitted with a strong piston rod continued into a guide for steadying the rod. The piston is formed somewhat greater in length than the length of the stroke of the engine, and the cylinder made correspondingly long in proportion to give room for the piston and end clearances. The piston may be packed with a ring or rings at or near to each end, and the cylinder is fitted with covers and stuffing box much in the usual manner. A strong lateral pin or arm about the same length as that of the stroke of the engine is fitted into the piston rod; this arm has formed on its end a spherical ball or knob and fitted upon it a correspondingly shaped bush, which bush in turn is placed in a hole or slot in a crank or disc, which is keyed or formed upon the revolving shaft, usually termed the crank shaft of the engine. The inner surface of this bush is correspondingly spherical and formed in halves to get on to its seat; its outer surface may be round or square, but must have room in the hole or slot in which it is placed for a slight play longitudinally in the direction of the length of the crank shaft; the distance from the centre of this bush to the centre of the crank shaft determining the throw of the crank, and as usual double this length fixes or forms the length of the stroke of the engine. The crank and crank shaft thus

coupled to the piston rod, it will be seen that on the piston being traversed from the end of the cylinder, besides its longitudinal motion, the arm fixed in the piston rod passing round with the crank bush and disc will also impart to the piston a sectional, angular, or turning reciprocating motion to the piston rod, and corresponding angular turning or twisting motion between the surface of the long piston and the internal surface of the cylinder. This sliding twisting motion of the piston on the surface of the cylinder is made available for the opening and closing of induction and eduction passages of the steam to and from the cylinder. The steam passages being formed in the piston and cylinder no steam slide or other regulating valves or motions are required for this form of engine, which simplification is the main novelty and object sought for. In one form of these engines one steam port and two exhaust ports are placed near to the centre of the length of the cylinder and in a parallel plane with the cover of the cylinder, their distances apart and spaces being determined by the extent of twisting motion given to the piston while they are short in the direction of the length of the cylinder. Two longitudinal slots or passages are cut in the piston in suitable positions the full length of the stroke, or nearly so, opening out to the periphery of the piston, but bent inwards at the ends where the packing rings of the piston are placed, one passing out at each end of the piston, and so far in turn, being both steam and exhaust passages alternately, their distance apart being such as will open the steam passage and one exhaust passage at the same instant, and when the piston traverses to the opposite port and end of the cylinder the steam passage will be opened to it, and the exhaust correspondingly opened to the other end. In this form of the steam passages there is little "lap" required or manageable, and the steam is not wrought expansively, but the motions and positions are suitable for small steam engines, for donkey feed engines, and pumps for water, air, or gas, the pumps of which may be wrought direct from the piston rod, and the same description of passages wrought by the same twisting motion may be used in the pumps for the induction and exhaust of the fluids, or ordinary self-opening and closing valves used as may be desired. For water meters the cylinders would be brass cased, and leather, rubber, or other packings be used. Both for steam engines, pumps, and water meters two cylinders may be combined together and connected with separate discs or cranks set at right angles in many ways, or the cylinders can be set at right angles and fixed to one crank motion.

For working steam expansively separate pairs of steam and exhaust ports are necessary, and the steam passage in the periphery of the piston instead of being cut nearly the full length longitudinally in the piston, as already described and explained, is only cut one-third or one-half the length of the stroke, according to the degree of "cut-off" required, whilst the exhaust passages can be readily so formed and placed as to be kept nearly full open for the most part of the stroke. The steam ports may be made long in the cylinder as well as in the piston. It will generally be an advantage to work these engines in a horizontal position, and admit the steam on the under side of the cylinder, so as to allow the position to lie on the ports and have the tendency to wear counteracted by the pressure of steam in the ports tending to bear up its weight. This form of engine is also suitable for working by the improved mode of utilizing the force of steam by returning the exhaust steam to the forcing side of the piston, described under the second head or section of this said Invention, the inducing jets or injectors by preference being placed in the piston, and the passages formed to suit and be regulated by being in part passed through the cylinder, while the condensed water can be taken through the piston rod to the feed pump. In appyling these improvements under the third head to marine engines, high and low pressure cylinders can be coupled on one piston rod, or the guide end of the rod can be made available for actuating an air pump or a forcing pump direct to it. In coupling two engines at right angles the centre of the piston rod of one of the cylinders could be formed like a crank, and the other cylinder fitted with a straight arm, and both coupled by bushes on to one crank by a crank pin piece.

Another improvement under this third head is for the regulation or governing the speed of fluid pressure motive-power engines, and consists in the use of various equivalent forms of small sectional turbine-formed wheels or discs, or pendulous valve pieces with a slanting opening or openings of a "louver board" or other equivalent shape balanced by a spring or by a weighted lever, or in the manner of a pendulum against the power or "speed flow" of the actuating fluid passing through the openings in the piece fitted within the egress pipe, the openings being reduced in size, or so formed as to contract the openings or shut off the flow of the fluid current when the speed of the current gets in excess of its normal motion, and so regulate the speed of the engines; the centre of oscillation and gravity of the balance

weight or pendulum may be made to vary by the pressure of the fluid or steam; the flow of the current in the ingress pipe acting both as a throttle valve and governor and without being connected by mechanical gear to the engine. This regulator is enclosed in a case forming part of the steam or fluid ingress pipe, and will be suitable for marine and other engines. The weight of the regulating piece or valve may be made to act simply as a balance weight against the pressure of the current, or be made to act or beat time as a pendulum by the current being made to act like an escapement wheel, in which latter form it may be used for approximately measuring fluids, the pendulum being connected to indices to register quantities in the usual manner.

The last improvement under this third head is for raising or reducing the speed of motive engines when the speed required is higher or lower than what is convenient in these improved or other motive-power engines, and consists in employing friction wheels on or at the first motion or crank shaft having the periphery of one of the large ones covered with leather or such "belting" substance placed in a groove, annular recess, or seat, one end of the strap being made fast, by preference, into a mortice and then stretched right round in the direction of motion and strain to the other end, which is drawn through a transverse slot or slots when various widths and lengths of stripes are used in the periphery of the wheel and close to where the first end is fastened, when one strap fills or completes the circumference, and means taken by a roller or other "tauting" apparatus to draw up the strap on the inside of the slot, as the leather or other equivalent strap used stretches in the direction of the force transmitted, being made to tend or tighten up the strap. The wheel with which it gears by preference having a plain metallic surface without leather or other such tensile substance, the leather or other tensile strap on the one wheel, as explained, gearing with the periphery of a plain surface wheel in the other by "stiff" rolling or frictional contact. A convenient arrangement for drawing the wheels in and out of contact to act as a clutch, and for maintaining the requisite frictional contact between the wheel surface is obtained by placing an adjustible eccentric bush in the eye of the driving or driven wheel.

SPECIFICATION in pursuance of the conditions of the Letters Patent, filed by the said James Robertson in the Great Seal Patent Office on the 13th April 1869.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, JAMES ROBERTSON, of the City of Glasgow, in the County of Lanark, North Britain, Engineer, send greeting.

WHEREAS Her most Excellent Majesty Queen Victoria, by Her Letters Patent, bearing date the Fourteenth day of October, in the year of our Lord One thousand eight hundred and sixty-eight, in the thirty-second year of Her reign, did, for Herself, Her heirs and successors, give and grant unto me, the said James Robertson, Her special licence that I, the said James Robertson, my executors, administrators, and assigns, or such others as I, the said James Robertson, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, an Invention for "NEW OR IMPROVED MODES OF OBTAINING AND TRANSMITTING MOTIVE POWER, AND IN THE MEANS, APPARATUS, OR MECHANISM EMPLOYED THEREFOR, PART OF SUCH APPARATUS OR MECHANISM BEING ALSO APPLICABLE TO THE MEASURING OF FLUIDS," upon the condition (amongst others) that I, the said James Robertson, my executors or administrators, by an instrument in writing under my, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal Patent Office within six calendar months next and immediately after the date of the said Letters Patent.

NOW KNOW YE, that I, the said James Robertson, do hereby declare the nature of my said Invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement in writing, reference being had to the accompanying thirteen Sheets of Drawings, and to the several figures, letters, and numerals marked thereon, that is to say :—

My said Invention under the first head or section consists mainly and generally in new or improved modes of generating and heating, or

producing fluid currents for actuating motive-power engines generally, and under the second head or section my Invention consists in new or improved modes of transmitting motive power to, in, and through, or by mechanism or engines constructed so as to have one actuating fluid of each motor introduced, forced, or injected in the form of a jet or stream through an annular nozzle or other conduit made so as to draw another or second fluid or fluids into and through the main duct, or it may be the partially spent currents of the same actuating fluid or fluids which have first passed through the motor as the actuating body, but which have still some force, heat, or other property left which it is or may be desirable and profitable to utilize, either alone or along with the said secondary induced fluids or any desired proportion of these and the partially spent or return currents, and in the directing and applying such combined or compound currents all so as to actuate the motive-power engine or mechanism by the force and expansion of such combined fluid currents (whether liquids, as water, or the more elastic gaseous fluids, such as air, steam, or the gaseous products of combustion, are employed separately or jointly), in each or either of these cases, and whether applied to rectilineal, reciprocating, or rotatory classes of mechanical motors or engines, whether the inital or secondary currents are produced in generators of the ordinary construction or by the new or improved modes and means of generating steam under the first head or section of my said Invention, and under the third head or section my said Invention consists mainly in new or improved modes of regulating the flow of the actuating or measured fluids to and from the cylinders of reciprocating motive-power engines, fluid meters, or measuring machines by forming the ports in and through the working surfaces of the cylinder and piston so as to form also the induction or eduction valve or valves (with or without inducing action or positively spent currents) and their fluid-tight working surfaces, and by giving the piston an oscillatory motion on its axis in the well known and proper sequential time and relative position to suit that of its own longitudinal reciprocatory motion instead of the separate slide and other valves usually employed for the like purposes. The parts of my said Invention under all of these heads or sections are susceptible of very many modifications and adaptations to suit the particular fluids and mechanical construction of force, generating and transmitting apparatus or engine, and the purposes for which these are to be applied, all of which improvements forming this my said Invention make motive-

power mechanism or engines constructed in accordance therewith more simple both in their construction and action, all so as to be produced and maintained thereafter in action at a less cost or more economically respectively and generally than they have been as heretofore constructed.

And in order that my said Invention and the manner of performing the same may be properly understood I shall now proceed to describe the several Figures on the said thirteen explanatory Sheets of Drawings, all substantially constructed in accordance with and illustrative of the best modifications and arrangements for practically performing or carrying the several improvements contained in my said Invention into effect or practice, which I am at present aware of, and which I have hereunto appended for that purpose, reference being had to these several figures and respective letters and numerals marked thereon which so far as possible are made to represent the same and equivalent or like parts in all the Figures.

The improvements under the first head or section of my said Invention, which are illustrative of and herein-after described in reference to the various Figures on Sheets 1, 2, 3, of the Drawings, consist substantially of a mode or modes of generating a current of steam, vapour, or gases so as to actuate motive-power engines, by which the water or other fluid to be used or acted upon is for the most part heated by direct contact with the fuel in a state of combustion, or by the heated gases eliminated therefrom, instead of the heat being transmitted through plates to the water or fluid to be heated, as is done in generating steam in a common boiler and steam generators heretofore. The water or fluid to be heated in this new manner is kept from mixing with fuel by being in a state of motion, and by having in the duct or channel for the passage of the fluid an opening or openings for the flame or heated gases at a high temperature to pass through and act on the fluid so as to convert it into steam or vapour, or to rarify, expand, and increase it in volume, and thereby accelerate its motion and increase its force. The fluid to be heated and expanded into steam or vapour is set in motion in the form of a jet or jets by the gravitation of an overhead column, or by forcing pumps of any kind, which may have an air vessel attached to make the jet or jets attached play continuously, or by a Giffard's injector or other similar apparatus. The efficiency of this new mode of generating steam or vapour will also be greatly increased by having the water to be acted

upon at as high a temperature as possible before it is introduced into the heating furnace; and one convenient mode of heating the water and obtaining the necessary pressure which I prefer to employ is the use of a small steam boiler of any ordinary form used for steam engines interposed between the forcing apparatus for the feed water and the generator, the pressure, motion, or initial force by which the fluid is made to enter and pass into the heating duct or channel mainly determining the pressure or force at which the steam or motive fluid is ejected from the heating pipe.

Referring to Sheet 1, Figures 1 to 24 show sections and elevations of various modifications of the most suitable forms of the heating channels for the conversion of the liquid into vapour or water into steam, which is mixed with the gases from the furnace, and the form of channels and their nozzles and jets therein shown as intended to act on water only, and afterwards as I proceed I shall describe the forms of the furnaces and the position of the heating channels in them. In all the Figures illustrating these motive fluid generators, and throughout all the Drawings hereunto appended, I make black arrows indicate the course of water currents, blue arrows to indicate that of steam or motive fluid, red arrows that of the flame or heated products of combustion or gases, and yellow arrows that of the currents of cold air, where such currents pass, occur, or are generated, whilst I make darts of these several colours respectively to indicate the course of return currents of the same kind.

Figure 1 is a sectional elevation, and Figure 2 an external elevation of a trumpet-shaped heating channel D and small cylindrical jet pipe A, with a jet of water the current of which is indicated by the black arrows as being made to enter the jet pipe A at a high pressure, and play in a small cylindrical jet through the correspondingly shaped nozzle A^1 across the space B, B^1, and through the trumpet-shaped heating channel D, as indicated by the blue arrows. The jet of water in the space B, B^1, being exposed, as herein-after described in reference to the general arrangement of generators shown on Sheets 2 and 3, to the heated gases of a furnace at a high temperature becomes heated and expanded into steam, and induces or draws in with it into the channel D the heated gases, which further expand the combined volume of steam and gases and accelerates its speed or force and pressure. The heating channel D is shown as broken off in these Figures, but is continued in the general arrangements just referred to, and to be herein-after described, when placed in a furnace for

generating and conveying the motive fluid to impel motive engines. The diameter or volume of the nozzle and jet A^1 required depends on the pressure and temperature at which it is admitted and supplied through the pipe A, and the temperature of the furnace for its power of converting it into steam, and the distance B, B^1, fixed between the throat D^1 or nearest part of the heating channel D depends on the heating power of the furnace to convert the water into steam, and the solidity and speed at which the pressure makes the jet to play across that distance or through the heating channel D. The diameter of the throat D^1 should be as small as will allow a sufficient quantity of the heated gases to pass through it to convert the water into vapour, and the continuation of the channel D is made to widen out as shown, more or less as the pressure or force of the motive fluid may be required.

The proportions shown in the Drawings, from Figures 1 to 15, are suitable generally for generating steam or vapour at low pressures as for actuating motors or turbines such as herein-after described; smaller diameters being necessary as higher pressures of vapour are required. These requirements of proportion are more or less applicable to all the other forms of jets and heating channels shown in the several Figures, and I shall therefore in further describing them refer chiefly to their forms and the direction the currents are made to pass through them.

Figure 3 is a sectional elevation, and Figure 4 an external elevation of a heating channel and jet pipe; the jet pipe A and the jet nozzle A^1 being similar to that shown in Figure 1. The heating channel D is shown composed in this case of four pieces of tube, the throat piece D^1 being smaller in external diameter than the internal diameter of the succeeding tube D^2, so as to enter into it a short distance and leave an annular space between the outer and inner circumference or surface of the two tubes, and in like manner as shown in the Drawings, the same relative positions and sizes are maintained between the successive pieces D^2, D^3, and D^4, so as to leave an annular opening at the end of each piece, as seen in the section Figure 3. On the jet of water being made to play through the channel D, as indicated by the black arrows, the heated gases will not only be induced or drawn in at the mouth of the throat D^1, (as shown and described in reference to Figures 1 and 2,) but at each successive annular opening referred to between the adjacent pieces D^1, D^2, D^3, and D^4, as indicated by the red arrows, and further expand and accelerate the motion of the steam as it passes along the

channel D. The relative positions of the several pieces of tube composing the heating channel D are maintained by being fixed in the bracket *c*, which is adapted by the sole piece *c* to be fixed inside a furnace.

Figure 5 is a sectional elevation, Figure 6 an external elevation, Figure 7 a plan, and Figure 8 a sectional plan through *a*, *b*, of a heating channel D composed of one casting, and with a series of slanting openings *d* leading from its outer to its inner surface. The form and angle of these openings in a cross section is shown in the sectional plan Figure 8, and the whole of the outer surface of this form of heating channel from the flange D^2 to its lower extremity is to be exposed to the heated gases of a furnace; and on water at a pressure being made to pass through the pipe A, and thence upwards, as indicated by the black arrows, the heated gases from the furnace are induced or drawn in at or by the openings *d*, as indicated by the red arrows, and convert the water into steam, escaping at the top, as indicated by the blue arrows. This heating channel is provided with a flange D^3 for connecting pipes to lead the steam or vapour away to actuate motive-power engines.

For regulating or contracting the jet orifice A^1 a cylindrical brass regulating conical tap or regulator C is shown in section in Figure 5, which has suitable snugs formed upon it for bolting to corresponding snugs formed on the heating channel D, seen in Figure 6 at *e*. This regulator has a branch *f* formed upon it, to which the water pipe A is connected, and admits the water to the chamber f^1 of the regulator C, which is provided with a sliding key, plug, or tap piece C^1, working out through the stuffing box C^{11}; the upper extremity of this tap piece is made acutely conical, similar to the regulator of a Giffard's injector, and fits and works into the small opening A^1, so as to close it entirely, or by withdrawing the tap to leave it wholly or partially open, so as to regulate the volume of the jet or quantity of water passing out through the nozzle A^1 to be converted into steam. The lower end of the tap regulator C^1 is shown connected to a regulating lever C^2 wrought on the fulcrum C^3, which can either be regulated by hand or connected by the jointed end C^{111} to any ordinary governor of a steam engine, so as to regulate the quantity of water and by it the quantity of steam required. The form of the tap and opening of this regulator C will be better seen by the enlarged sectional elevation of it shown in Figure 25.

This form of heating channel D instead of being cast in one piece, as described in reference to Figures 5 to 8, may be composed of a series of separate conical castings, so as to give it a similar form.

Figure 9 is a sectional side elevation, Figure 10 a front elevation, and Figure 11 an end view of a heating channel D provided with a water pipe A and jet orifice A^1 in the form of a very narrow slit of the length, as shown, nearly the breadth of the external aperture or surface of the heating channel, so as to give a jet in the form of a thin sheet of water. The heating channel in this case is composed of two rows of transverse tapering plates D^1, D^2, D^3, D^4, D^5, D^6, and D^7, on one side of the jet space, and a corresponding series of plates on the other side of the jet d^1, d^2, d^3, d^4, d^5, d^6, and d^7; these plates overlap each other, and spaces are left between them at the under side of each for the heated gases entering between them, as indicated by the red arrows. These plates D^1 to D^7 and d^1 to d^7 have flanges cast upon them at their ends, and are bolted to the side plates D and D; the discharge end has bolted to it a trumpet-shaped pipe E with an oblong mouth, shown as broken off, which completes the heating channel. On water being forced through the pipe A, as indicated by the black arrow, at a high pressure, a thin sheet or film of water or spray will be ejected up through the space between the plates composing the heating channel D, and when placed in a furnace it will induce the heated gases in at the openings between the plates, as indicated by and at the red arrows, and the steam or vapour which is ejected through the pipe E, as indicated by the blue arrows, can be led away to actuate a steam or motive-power engine.

Figure 12 is a sectional elevation, and Figure 13 is a partial transverse section through or on the line *a*, *b*, in Figure 12, of another form of the heating channel. In this case the water pipe A is formed with a small cylindrical jet nozzle similar to that shown in Figures 1 and 2, and the space or length of the heating channel D, on the concave and under side is exposed in a furnace to the action of the heated gases, the heating channel as will be seen in Figure 12, and is thereafter narrowed into a throat at D^1 and continued on in an expanding pipe to carry off the vapour.

Figure 13 shows the cross section of the heating channel D where it is open as from B, B^1, on the under side and formed in the shape of an inverted U (∩) with small "rone" or gutter channels formed at each side of the under edges. On water being made to pass through

the pipe A as indicated by the black arrows, the nozzle A^1 is placed to play into the concave side of the heating channel D, and causes it to spread and allow of the heating action of the gases to act on a less dense body of water than is presented in the cylindrical jet so as to be converted into vapour more readily, although with a somewhat diminished force owing to the retardation by friction on the sides of the channel, the passage of the heat, gases, and vapour being indicated by the red and blue arrows.

Figure 14 is a sectional elevation, and Figure 15, an external elevation of a jet pipe A and heating channel D, in which the nozzle A^1 is entered into the bell mouth of the heating channel D, otherwise the form of the pipe A, nozzle and heating pipe D is similar to that described in connection with Figures 1 and 2. In the arrangement shown in Figures 14 and 15 the jet is not directly latterally exposed to the heated gases of the furnace, but the gases are induced or drawn in at the bell mouth of the heating channel D^{11} and with water form a boiler at a very high pressure, when it expands with a little accession of heat from the gases into steam and has a great tendency to spread, this arrangement with a high temperature in the furnace is suitable, the current of the water, heated gases, and vapour is indicated by the black, red, and blue arrows.

Figure 16 is a sectional elevation, Figure 17 an external elevation, and Figure 18 a plan of a heating channel and water pipe with an annular nozzle, the access or induction current of the heated gases also to the water as in the form just described only being at the end of the heating channel D as indicated by the red arrow, and is suitable also for water at a very high pressure, and with the furnace gases also at high temperatures. The water is passed through pipe A into the annular space A^3 of the nozzle piece A^2, and issues with great force in a thin film at the annular nozzle A^1 as indicated by the black arrows inducing in the heated gases, and the steam generated therefrom mixing with the gases is ejected through the heating channel D as indicated by the blue arrows.

Figure 19 is a sectional elevation, and Figure 20 an external plan of the upper part of a furnace in which a forcing jet or nozzle A^2 of the same form as that described in connection with Figures 16 to 18 is used, the space into which the water is forced and annular nozzles being seen in Figure 19, and the branch pipe A seen in Figure 20, the direction of the water current being indicated by the black arrows. The heating

channel D is shown passed through the side of the furnace and provided with a central core piece d^{11} to narrow the throat D^1, and allow the steam and gases to take the direct course from the issuing of the annular jet of water from the nozzle A^1. The heated gases are by the curved branch pipe *i* led at both ends from the top of the furnace into the central branch i^1 to which the water nozzle piece A^2 is fixed, and the gases induced in through the pipe *i*, *i*, and down through the space in the centre of the nozzle A^2, and thereby made to play with the water into the mouth of the heating channel D, the course of the heated gases being as indicated by the blue arrows, and the steam or vapour being ejected through the channel D as indicated by the blue arrows.

Figure 21 is a sectional elevation, and Figure 22 an external elevation of a jet pipe A and heating channel D, which is adapted to convert the water into steam by the exposure of the jet to the heated gases of a furnace in the space B, B^1, between the jet nozzle A^1 and the throat D^1 of the heating channel, without inducing the gases from the furnace along with it or as small a portion thereof as may be found practicable. For this purpose the throat or narrowest part D^1 of the heating channel D, forming the mouth of the channel, is made sharp at the edges, and tends to divert the heating gases aside instead of inducing them in along with the water, and the steam generated in the space B, B^1, as described in connection with Figures 1 and 2, the course of the currents of water and steam being indicated as before named by the black arrows and blue arrows.

Figure 23 is a sectional elevation, and Figure 24 an external elevation of a heating channel, adapted for being placed in a furnace substantially as described in connection with Figures 5 and 6, but with openings adapted for the water jet to play up through it so as to receive or absorb the heat, without inducing the heated gases, or as small a portion of the gases as possible, so as to obtain pure steam or steam approximately pure. For this purpose the small openings *d*, *d*, *d*, at the foot, where the water will give off very little vapour, are slanted in a downward or backward direction into the inside of the heating channel D, and the direction of these openings as they approach the top of the channel are gradually changed until as shown they are slanted in an upward direction, but sufficient only to prevent the vapour passing outwards through these openings, otherwise the form of this heating channel is similar to that described in connection with Figures 5 and 6, and

although these various forms of heating channels D have been described and shown as constructed of iron, they may be constructed of any other suitable material which would stand the heat, as fire-clay.

Figure 25 is a side elevation, partly in section, and Figure 26 a plan of a regulator for regulating the quantity or volume of water to be passed up through these heating channels, similar to that described in connection with Figures 5 and 6. This enlarged view of the regulator is chiefly given to show an apparatus for disintegrating or breaking up the jet of water passing up from the nozzle A^1 into spray, so as to allow the heated gases to act on it with more heating effect, and consists in placing sharp pointed needles or breakers in a conical or other holder j^1 a short distance above the nozzle A^1, there being six of these needles or breakers shown partially entering the current, seen more distinctly in Figure 26, and the jet striking these in swift motion is effectually broken up into spray. The needle holder j is fixed on a sliding bar j^{11} which is adjusted in a slot in the regulator and fixed by a set pin.

Figure 27 is a sectional elevation, and Figure 28 a plan of a similar jet regulator, the only difference of this regulator from that shown by Figures 25 and 26 consists in the nozzle A^1, which instead of being circular is star shaped, and the sliding tap or key C^1 correspondingly shaped as seen in Figure 28, so as to cause the water jet to pass out mainly in thin films.

Figure 29 is a side elevation; Figure 30 an edge elevation both partly in section, and Figure 31 a plan of a similar water jet regulator for the like purpose, the only difference from that described in reference to Figures 27 and 28 being in the form of the jet nozzle A^1 which is oblong and the point of the tap regulator wedge shaped, so as to cause the water jet to pass out in a thin film; the object of these different modifications of the nozzles is to present the jets in as an attenuated form as possible so as to be more susceptible to the heating action of the furnace.

Figure 32 is a sectional elevation, and Figure 33 a sectional plan on Sheet 2 of my Drawings, showing a form of furnace somewhat resembling the ordinary reverberatory furnace for burning fuel and heating the air and gases in the furnace to a high temperature to act on jets or currents of water so as to convert them in their passage through the furnace into steam combined with gases produced by the air and combustion of the fuel, all in accordance with one modification under this

first head or section of my said Invention. The form of heating channel is similar to that described in connection with Figures 1 and 2 on Sheet 1 of my Drawings as shown and described in reference thereto. One water pipe A conveys the water to three jet nozzles A^1 through the cross branch pipe A^2 as indicated by the black arrows, the jets being made to play across the space or distance B, B^1, in the furnace into the three heating channels D, which converge into one channel or pipe E for conveying the vapour to a motive-power engine, the course of the vapour currents being as indicated by the blue arrows, the red arrows showing the heated gases entering the heating channels. In this arrangement the furnace is constructed of brick and provided with a furnace mouth and doors G, set of furnace bars G^1, flame bridge G^2, chimney G^3, and is of the most simple description, but almost any form of furnace that will consume fuel and heat the gases economically is also suitable. The chimney G^3 is provided with a damper G^4, which after the furnace is heated and the water made to play across the furnace (Figure 33) is shut or partially so, so as to allow the water jets to induce, draw in, or force a portion or all of the waste heated gases from the furnace as a motive fluid, and thereby utilize all or nearly all of the heat from the fuel.

Figure 34 is a plan, Figure 35 a front sectional elevation, and Figure 36 a side elevation of a furnace adapted for generating vapour in a heating channel of the construction described in connection with Figures 5 to 8 on Sheet 1 of my Drawings, the course of the currents of water, heated gases, and vapour being indicated by the arrows. The furnace is of a square vertical form composed of brick fitted with a furnace mouth G, set of fire-bars G^1 covered in on the top by the plate H, on which the heating channel D is suspended by the flange D^2 and having a funnel G^3 also fixed on the plate H which is fitted with a damper G^4. The management and action of this furnace is very similar to that just described in connection with Figures 32 and 33; the vapour generated is led away from the heating channel D by the pipe E jointed to its upper flange D^3 to any suitable motive-power engine.

Figure 37 is a sectional elevation, and Figure 38 a plan partly shown in section through the line *a*, *b*, Figure 37, of a motive fluid generator in which the form of the heating channel D is similar to that described in connection with Figures 3 and 4 on Sheet 1 of my Drawings; and the furnace proper is composed of a cylindrical sheet of boiler

plate I egg-shaped at the top fitted with a furnace door G set of fire-bars G^1, funnel G^3, and damper G^4. The water to be converted into steam or vapour is admitted by the pipe A under pressure into the chamber A^2, and from thence it passes into the coil pipe A^{11} which is led up near to and opposite the heating channel D, and terminated in a suitable nozzle A^1. The use of the coil pipe A^{11} is to impart a portion of the heat of the furnace to the water before it reaches the nozzle A^1. The vessel A^2 which has its top end on a level with the jet nozzle A^1, is adapted to contain a quantity of water for the purpose of keeping the coil pipe A^{11} always full of water, and prevent its becoming injured by the great heat of the furnace when the water is shut off from the main supply at the pipe A, a cock A^3 is provided for shutting off or regulating the water from the vessel or tank A^2 into or entering the coil pipe A^{11}. The course and action of the currents of water, heated gases, and vapour are as indicated by the arrows, and the action and arrangement of this furnace and the heater D is otherwise similar to that just described (and in reference to Figures 3 and 4).

Figure 39 is a sectional elevation, and Figure 40 a sectional plan through the line *a*, *b*, in Figure 39, of a furnace for generating vapour by heat from the combustion of carburetted hydrogen (common) gas, or any suitable combustible gas; the furnace is constructed of cast-iron cylinders I, lined as shown by fire-brick and fitted with a top plate H; a heating channel D is shown applied of the same form as that described in connection with Figures 5 and 6, on Sheet 1 of my Drawings, suspended by the flange D^2 from the top plate H. The inflammable gas is admitted by the pipe J^1 which is a continuation of the coil pipe J outwards. The coil pipe J is provided with a series of jet burners J^2 throughout its length, similar to the common illuminating gas burner, as indicated, affixed in the coil pipe J. On gas being admitted to the coil and ignited at the burners J^2 it heats the furnace in lieu of coal or other fuel. A small funnel G^3 provides an outlet for the waste gases when the water jet is shut off and damper G^4 for closing or partially closing the outlet of the waste gases when the furnace is in action; a somewhat similar arrangement can be made to generate steam or vapour in this way by the use of petroleum oil as fuel instead of the gas.

Figure 41 on Sheet 3 of my Drawings is a sectional elevation of an "iron puddling furnace" with a series of jet-heating channels shown affixed or arranged and applied in the main chimney G^3 for carrying off

the waste heated gases therefrom; Figure 42 is a sectional plan of the chimney showing a horizontal section of one of this modification of heating channels A, A^1, and D, seen in sectional elevation in Figure 41. The form of the water jet pipe A, nozzle A^1, and heating channel D used in this modification is similar to that described in connection with Figures 1 and 2 on Sheet 1 of my Drawings, nine sets of these being ranged or placed successively over each other in the main chimney G^3; the whole nine jets A^1 of the set being supplied from or by one common water pipe A leading into them placed opposite to the mouths D^{11} of the nine channels D which are jointed into one common steam or motive vapour pipe E which is led down to the motor desired. The jets of water thus being made to play across the space of the chimney B, B^1, are highly heated in their course, and induce or draw and force in the heated gases from the furnace and chimney K into the heaters D, and with them convert the whole into an elastic motive-power vapour, the course of these fluid currents being indicated (as in the other modifications) by the black, red, and blue arrows respectively. In this way, by these my said improvements, the waste heat from puddling and other furnaces can be utilized most economically for producing a motive-power fluid.

Figure 43 is a side elevation, and Figure 44 a plan of a furnace and vapour generating apparatus, designed chiefly for supplying motive vapour or steam to engines which are intermittent in their action. In this modification the outer shell I of the furnace is cylindrical, constructed of boiler plate lined with fire-brick, having two furnace mouths or doors G, set of furnace bars G^1, and a chimney G^3, and damper G^4. On the top of this furnace is placed the vessel F, to the under side of which is bolted the heating channel D, inside the vessel F and opposite the heating channel D is bolted the trumpet-shaped pipe E fitted with the conical valve f, the regulating rod f^1 of which works out through the stuffing box f^2, the weight of these parts when necessary being borne up or balanced by the lever f^{11} (to which the valve rod is coupled) and balance weight f^{111}; the heating channel D in this case is similar to that described in connection with Figures 5 and 6, on Sheet 1 of my Drawings. On fuel being placed in the furnace and kept in a state of combustion, and the whole heated to a high temperature, a jet of water is made to play up the heating channel D and into the trumpet pipe E; the force of the current raises the valve f, and filling the vessel F passes out to the motive-power engine by the pipe F^1. If the engine is

intermittent in its action like a cylinder reciprocating piston steam engine the large volume of vapour in the vessel F compensates for the irregularity of the current outwards by receiving into itself the steady current from the heating channel D. A pipe and cock *h* is provided for carrying away the condensed water and impurities from the furnace that deposit "sediment" in the vessel F, and serves also to maintain regularity of the current from the heating channel D, and as explained serves to take away the granular impurities from the vapour passing through the vessel F; the currents of the several fluids being indicated by the black and coloured arrows respectively, as in the other modifications. To force a current of air into the furnace to support the combustion with closed furnace doors an annular injector *a* is provided fixed underneath the fire or grate hearth G^1 to induce and force in cold air by a jet of steam led from the vessel F by the cock a^1 and pipe a^2; the form of this jet ejector being similar to that described and shown in reference to Figures 16 and 17 on Sheet 1 of my Drawings; the damper and furnace doors when this arrangement is used are closed.

Figure 45 is a sectional elevation, Figure 46 a sectional plan through the line *a*, *b*, in Figure 45, and Figure 47 is an external end elevation of a heating furnace for a series of small jet nozzles and heating chambers, the jet nozzles A^1 being formed or fitted in the upper side of the closed vessel A^2; and the heating and receiving channels D are formed in the under side of the vessel F^2 placed as shown, with its under side "flush" with the inside of the top surface of the furnace. These jet nozzles A^1, A^1, are formed similar to that described in reference to Figures 1 and 2 on Sheet 1 of my Drawings, but made very short and small so as to cause each jet to require but little heat to convert it into steam or vapour. The pipe A leads forward the water to the vessel A^2, from which all the jets issue upwards into and through the small heating channels D, D, D, into the vessel F^2; and if the temperature of the furnace is too low to convert all the jets into vapour, also discharges or carries a portion in the form of water along with the vapour into the vessel F^2. The vapour is caused to issue from the pipe F^1, and the water not converted into vapour is led back by the hollow "rone" ducts *b*, *b*, *b*, *b*, between the small heating channels D into the main "rone" duct b^1, and caused to issue out at the pipe b^2, seen in dotted lines, and all as seen in the plan in Figure 46, and from whence the water is again passed through the pumps or other forcing apparatus

employed through the forcing entrance pipe A again. In this way cold water on starting can be made to pass through the furnace several times until it gets to the boiling point, in which state it is sent round in jets continuously, and only such a quantity of cold water supplied as is evaporated and made to escape in an elastic current through the pipe F^1. This mode or principle of returning the liquid current is more or less applicable to all the forms of heating channels described. The furnace of itself and mode of working it is similar to that described in connection with Figures 32 and 33 on Sheet 2 of my Drawings, and has an air forcing pipe jointed underneath the fire-bar (though this is not shown in the Figures) for working with closed furnace doors. The air may be induced or forced by a jet of steam or by any suitable means to increase the intensity of combustion and current of heated gases and motive vapour.

Figure 48 is a sectional elevation, and Figure 49 an external elevation of a vertical cylindrical dome-shaped boiler, Figure 49 being shown at right angles to Figure 48. The boiler I is of the ordinary internal fire-box dome-shaped form, constructed of boiler plate, having a cross tube I^1 inside the fire-box I^2. The Drawing will otherwise explain the general construction of the boiler I sufficiently. The boiler is fitted with safety valve and all the other ordinary mountings or fittings, and is filled with water up to the usual water level, and shown at H. A cock A and jet nozzle A^1 is fitted inside the cross tube I^1, which is wrought by the rod C^1; opposite this jet nozzle A^1 the heating channel D is placed vertically inside the steam space of the boiler I, with its throat D^1 set and opening through the top of the fire-box, and having its upper end passed through the opening K in the crown of the boiler, and formed conical on its top end surface *d*, the opening K bing wider than the external diameter of the channel D to allow the steam to pass freely, the channel D being secured in its position by the arms *c*. A vessel L is mounted on the top of the boiler I, and fitted with a safety valve L^1, on the top of which vessel L a stuffing box piece M is fitted with packing collar M^1, through which an adjustable pipe piece D^2 works by the regulating hand gearing N, N^1, and N^2. This pipe piece D^2 has its lower end made conically to fit the top end of the heating channel D, and is controlled by the hand joint lever N^2 either by the hand or by the governor of a motive-power engine. On steam being raised in the boiler I to an ordinary pressure of about forty pounds to the square inch, and the cock A opened and the steam-pipe piece D^2 raised slightly, the

steam will pass through the slanting opening *d* between it and the heating channel D and adjustable pipe-valve piece D^2, escaping through the pipe D^2, and cause an inducing action up through the heating channel D and aid the forcing action of the water jet to carry up the heated gases from the boiler furnace I^2, while the forcing action of the jet will enable higher pressures to be reached than attainable by the simple inducing jet action. In this way I combine my direct acting method of generating motive vapour with the common boiler.

Figure 50 is a sectional elevation of an arrangement for heating the water jet from the jet pipe A by waste steam. A cast-iron closed box A^{111} is placed in the side of the furnace, having coupled to it the waste or exhaust steam pipe O from an engine, and also the water-forcing jet pipe A. To the opposite side of the box A^{111} next to the furnace G^3 is fixed a secondary short jet pipe A^2, leaving the space B^{11}, B^{11}, inside the box A^{11} for the jet to play across the box, and form a partial vacuum, and becoming heated by the steam and thence passing through the nozzle pipe A^2 across the furnace space B, B^1, and through the heating channel D in the form of elastic vapour suitable for motive-power purposes, a waste water pipe *h* being provided for taking away condensed water from the box A^{111}.

Figure 51 is a sectional elevation, and Figure 52 an external plan of a form of furnace for utilizing waste steam, and for obtaining steam free, or approximately free from the gases of the furnace. This furnace is similar to that described in reference to Figures 34, 35, and 36, and is fitted with the same description of heating channel D, but placed in an inverted manner or form, the water jet pipe A sending the jet downwards and the vapour passing out by the pipe E coupled to the pipe D^1 and heating channel D. An outer heating channel D^3 of the same form, but larger in diameter, is made to surround the main one D to which the waste steam pipe O is coupled, thus surrounding the main heating channel D by a zone of steam, and being heated by the furnace its closer proximity and greater affinity for the water than the gases causes the steam to be united with the water and to evaporate the water, and the furnace is provided with a chimney G^3 and damper.

Figure 53 is a sectional elevation, and Figure 54 an external plan of a vessel for containing water for removing impurities from vapour generated by these several improved generators. It may be made of any convenient form, or constructed of any suitable material that will

stand the pressure necessary. This one is shown constructed as a close vertical cast-iron cylindrical vessel P, to which is connected the steam or vapour pipe D from the heater and generator, and the steam or vapour pipe E leading away the vapour to actuate a motive engine. In order to remove granular particles and other impurities from the vapour generated a partition H^1 dips down from the cover H below the water line 1, 1, in the vessel P, which makes the vapour entering at the pipe D^1 to pass through the water, and thereby causes it to leave all or a great portion of its impurities in the water, which get precipitated to the bottom before the vapour rises on the opposite side of the partition H^1 to escape by the pipe E to the engine. A sludge door P^1 is provided at the bottom for removing all deposit as it accumulates. To keep the water from getting too low in the vessel P and converted into steam, a small feed pipe *k* is provided, and a discharge hot water pipe *l* to be led to supply the jet water of the generators. With a vessel thus coupled to the pipe of the generators water can be withdrawn to work water engines from a cock, as at Q.

The essential and substantial improvements and features of novelty comprised under this first part or head of my said Invention as so far described is or consists in the use of a jet or jets of water or other liquid, vapour, air, or gas, and causing them to pass or "play" intermittently or in streams into heating vessels or through channels or nozzles, and into or through other liquids, air, or gases in a heated state within or drawn from furnaces, so as to be induced (or drawn in and forced) to intermingle or combine with the jets and generate a current by their initial force, which may be assisted by closed furnaces, and air forced in for the combustion of the fuel, and form a heated current of elastic fluid to be used for motive-power purposes, and also in the construction and arrangement of parts of the apparatus or mechanism and modes of using these for producing and conducting the said motive fluid, all substantially as herein described; and also in returning a part of the said initial water or current or produced vapour condensed to be reheated, as described; and further, also in these improvements or any of them separately for producing motive vapour, either in connection with an arrangement of ordinary open furnace or with closed doors on fire, ash-pit, and damper, and forced air currents, or currents produced with steam jets to produce forced combustion, all substantially as described.

My said Invention under the second head or section consists in various new or improved arrangements of apparatus for directing the force of steam or other motive vapour from a steam boiler or vapour generator, by a jet or jets to actuate the piston or other equivalent moving parts of motive-power engines, having or providing in combination with these arrangements a return channel for conducting the steam or vapour which has passed through the engine back to the induction or entrance port or nozzle of the jet or jets of steam from the steam generator, thus connecting the return channel for the exhaust steam or vapour from the motor, and the pipe from the steam boiler or generator, so that that part of the exhaust fluid which remains in a state of vapour or spray, and is not condensed into water by the abstraction of its heat or force by the engine, shall be induced by the action of the jet or jets of steam or vapour from the boiler or generator, and by the heat imparted thereto again expanded and sent through the engine again along with the fresh motive vapour; the condensed water from the steam in the return channel being trapped and led into a reservoir or pipe ready to be sent in a hot state by a pump injector or other equivalent means or apparatus back to the steam boiler or vapour generator, again to generate steam or vapour for the engine. The steam or vapour or portion thereof having as stated to pass several times through the engine before it is condensed into water, the most suitable form of motive-power engine is that which will act with a large volume of steam or vapour at a low pressure.

One modification of and means for carrying out the improvements under the second head of this Invention consists in the mechanical motor impelled part of it, which directly receives the force of the motive vapour, being in the form of an undershot or overshot water wheel, inclosed in a case with the axis by preference placed horizontally and having an annular inducing port or jet piece for the steam or vapour from the boiler to enter, connected to the rim of the case near to its top side, and an exhaust port placed about a sixth part of the circumference of the wheel or motor from the former; in passing through which inlet channel the current of motive vapour or fluid impinges on and forces forward the floats or vanes of the incased wheel or motor, until it reaches and escapes at the exhaust port or channel, The vanes of the rotating wheel or motor may be made curved or straight, and set in a nearly radial direction and formed the full width

of the wheel, but not required or made to fit the case accurately, and these induction and exhaust or return ports or channels for guiding the vapour to and from the vanes may have "louver board" pieces to direct and induce the current straight or tangentially through them and the wheel; and these channels may be formed in the outer case and be made to serve as a casing or jacket for the main case of the motor wheel or be led round to the steam inducing jet from the boiler or generator. The lower side of the return channel being provided with a trap opening or openings for the water from the condensed steam being trapped or led to a reservoir or pipe ready for the supplying the steam generator.

Figure 1 is a side elevation, and Figure 2 an end elevation on Sheet 4 of my Drawings, of a mechanical motor constructed in accordance with and illustrative of one modification of these improvements under the second head or section of my said Invention, so as to act on this induced and return current arrangement or principle, the working parts in both Figures being shown in section.

Figure 3 is a sectional elevation, and Figure 4 a transverse section of the inducing jet nozzle and other parts connected therewith, namely, the induction steam pipe A, annular induction jet nozzle piece A^1, return current nozzle piece A^2, and annular adjustable sliding valve piece A^3, as also part of the induction pipe A^4, which leads forward the motive vapour to the induction port B^4 in the case B of the motive wheel C. The form of the annular inducing nozzle A^1, which by preference is made of brass, and shown coloured yellow in Figure 3, will be better understood by referring to the enlarged detail Drawings, Figures 16, 17, and 18, on Sheet 1 of my Drawings; this form of jet inducing nozzle I prefer to use as being the best for utilizing the force of steam by this improved mode or principle of using return currents, and with slight modifications I have shown it applied to the various modifications of motive-power engines, which are actuated by this returned induced steam current modes of utilizing the force of steam, from Figure 1 on Sheet 4 to Figure 35, Sheet 6 of the Drawings hereunto appended. The motive wheel C, as shown in this modification, resembles the form of an undershot water wheel, and is composed of a centre piece C^1, two malleable iron side or end plates C^2, C^2, bolted to the ends of the centre piece C^1, and bound together near their outer rim or inner edge of the vanes by a circumferential rim or plate piece C^3 rivetted in between the

side plates C^2 and the vanes *c*, *c*, *c*, which are also made of thin iron plate, and rivetted to the side plates C^2 and to the circumferential plate C^3. The space between the vanes *c*, *c*, therefore forming a series of cavities or buckets, which contain the motive vapour in its course while or as it passes from the induction to the eduction port of the case. The form of the vanes *c*, *c*, may be curved radially, but I prefer them made straight, and placed as shown, inclined backwards at the points from the inlet side where the vapour impinges on them, so as to cause the vapour to pass out at the eduction or exhaust duct or port B^5 more freely than if left radial. The centre C^1 of the motive wheel C is fitted fast on a spindle D which works in the bushes B^1, B^1, formed in the sides of the case B, also supported and working in the bush bracket D^1, the sides of the case B and the bush bracket D^1 being bolted on the top of the cast-iron water cistern E; the whole of these stationary parts thus forming a compact and stiff framing for the impelled motive wheel C to revolve in. The spindle D is also fitted with the belt pulley D^2, which by a belt gives off the power transmitted to it. The circumferential rim plate B^2 of the motive wheel case B, which encloses the motive wheel C, has formed at its under side the branch pipe connection B^3, which is formed to carry off water from the condensation of the steam from the case B into the cistern E conducted down by the pipe E^1. The top section of this circumferential plate B^2 has formed in it for the course of the steam or vapour current the induction port B^4 and the exhaust port B^5. The induction pipe A^4 is connected to the induction port B^4, and the induction end of the return steam pipe F is connected to the exhaust port B^5. The induction and exhaust ports B^4, B^5, are shown fitted with a series of thin plates *b*, *b*, *b*, so as to guide on and lead off the motive steam to and from the vanes *c*, *c*, *c*, of the motive wheel B in thin streams or layers tangentially, and the ends of the plates *b* are cut off near to but so as not to touch the vanes *c* as the wheel C revolves, space being also left in the case all round for the vanes *c* and wheel to revolve; exact or accurate fitting not being necessary in these "low-pressure" engines. The return pipe F is shown led from the eduction to the induction side of the engine, and has connected to it at the induction side by a branch connection the escape pipe F^1 for waste steam, as also the pipe F^2 by a similar branch on the under side of the return steam pipe F, and opposite the waste steam pipe outlet branch F^1. The pipe F^2, which is connected to the water cistern E, and to which it leads down the water formed by condensation in the return pipe F. The pipe F^3 at the

exhaust side also being connected, as shown to the return pipe F and water cistern E to take down the water from the condensed steam. The return pipe F has formed in it an annular trap space F^4 near the steam branch pipes A and A^1 adapted to trap the water from condensation which adheres to the surface of the pipe, and to direct and conduct it down through the pipes F^2 and F^3, and thereby take the water from the return steam before it enters the nozzle pipe A^2, which nozzle pipe is in this case shown as cast in one piece with the return pipe F; but it might be formed in a separate piece, as seen in the detached sectional views, Figures 3 and 4, of the steam inducing nozzle combined with this return nozzle. The return nozzle piece A^2 has fitted to slide upon it the annular loose sluice or valve piece A^3, seen in Figures 1 and 3, which when pushed close to the steam injection nozzle piece A^1 excludes the air, but when drawn back allows the air to enter at the opening A^{11} at the end of the return nozzle A^2, as indicated by the yellow arrows. This slide valve A^3 may in this way be closed or opened according as the pressure of the steam or resistance to be overcome by the power of the engine my require. Thus arranged, and on steam from a steam generator or boiler being admitted by the pipe A in front, the steam and its annular nozzle A^1 induces or draws in the air that is in the return pipe F, and sends a strong current of steam and air in through the pipe A^4 and induction port B^4, guided on to the vanes *c* of the wheel C in thin streams by the plates or "louver boards" *b*, *b*, *b*, so as to impinge on the vanes *c*, and impel or force round the motive wheel C, as indicated by the arrows at *c* passing out through the exhaust port B^5 in thin streams between the plates or "louver boards" *b* fitted in this port also, so that as each vane *c* comes round to the first plate *b* the current on the top of the first plate tends to induce or draw out the layer of steam flowing out through the space or spaces below it, and so on successively down as each vane of the wheel passes the exhaust port B^5, and thereby effectively exhausts the steam from the cavities or buckets of the wheel before fully passing this port. The exhaust steam thence passes round through the return pipe F, as indicated by the blue darts, being partially condensed into water in its course, but whatever air or steam is not condensed is induced in through the return steam nozzle pipe A^2 of the annular nozzle injector A^1 by the initial inducing jet of steam through it, and sent along with the initial steam from the boiler again to act over the vanes of the motive wheel C, and so on continuously, the course of the currents being as indicated by the blue, yellow, and black arrows; the

blue darts showing the course of the return stream of steam or air. Whatever exhaust return steam is not induced in through the nozzle A^2 to the motive wheel C of the engine again escapes by the waste steam pipe F^1, and the water from the condensed steam passes down through the pipes F^2 and F^3 into the water cistern E, from which cistern E the water at a high temperature is drawn away to feed the steam generator or boiler through the water pipe G, the currents of which and motion of the engine being all as indicated by the darts and arrows as before named.

Figure 5 is a sectional side elevation, and Figure 6 an external elevation of an impact motive wheel or engine of the same general description as that just described in reference to Figures 1, 2, 3, and 4, but designed for greater power and larger in diameter, having also three inducing steam injectors and corresponding three separate inducing ports and exhaust ports leading the steam or vapour on, upon, and out from the motive wheel at separate and at equal distances from each other into the case. Each inducing nozzle and its induction port induces the steam from the exhaust port next to it. The same letters refer to similar parts as in Figures 1, 2, 3, and 4. Steam is admitted from the steam generator or boiler by the inlet branch and steam cock A^5 and pipe A, A, A, to the three annular nozzle steam-inducing injectors A^1, A^1, A^1, which severally, as explained in connection with Figures 1 and 2, send a current of steam or vapour through the induction port B^4 to which it is connected, and to the vanes *c*, *c*, *c*, of the motive wheel C intervening, and through the exhaust port B^5, and passing through the return pipe F, as indicated by the blue darts, and then induced into the successive induction ports B^{11}, B^{111}, and what the inducing nozzle does not take in escapes by the waste steam pipes F^1, the condensed water being trapped by the annular traps F^4, F^4, F^4, in the bent return pipes F, F, F, by the return water pipes F^2, F^3, and branch pipe F^5, to the water cistern E, the water from which cistern being led to the boiler by the pipe G. A waste steam pipe E^2 is connected to the top part of the water cistern E for conveying away the waste steam (if any) which may pass into the cistern by the branch pipe F^3 from the lower return pipe F. Thus arranged three successive currents of motive vapour are made to impinge and impell the motive wheel C at three corresponding sections of its circumference, and thereby by consuming and utilizing corresponding steam by each inducing injector obtains increased and

correspondingly greater power than would be obtained from one set of ports. The course of the currents of steam and water are as indicated by the arrows and darts.

Figure 7 is an external plan, Figure 8 an elevation partly in section of a similar motive-power engine to that described in connection with Figures 1 and 2, but having two steam induction ports B^4, B^4, on one side of the wheel case B, one at the upper, and the other at the under side, with corresponding escape or exhaust ports B^5, B^5, at the upper and under sides opposite the induction ports for being used or for making the vapour current pass from either induction port for the purpose of reversing the motion of the motive wheel C. The return steam pipes F, F, are bent round and along at the side of the case B, as seen in plan Figure 7, and have a separate set of pipes for each pair of induction and exhaust ports, but otherwise there is no substantial difference in this engine from that described in connection with Figures 1 and 2, and the same letters refer to the same parts in each. The branch steam pipe A has fixed in it the three-way cock A^{111}, which by turning the handle on its key introduces the steam to the top side inducing injector A^1, or to the bottom inducing injector A^2, which produces corresponding reverse motions in the motive wheel C. The course of the currents in the return pipes F, and the flow of the water to the cistern E through the pipes F^2 and F^3 are as indicated by the arrows. Although the motion of the motive wheel C is made to reverse the course of the currents of the steam and water do not reverse in these pipes, one set remains empty while the others are in action or use, in this way an effective reversing motion is obtained.

Figure 9 is an elevation of a motive-power engine composed of two combined motive-power engines, each similar to that described in connection with Figures 1 and 2. The object of this arrangement is to cause the exhaust vapour from the first motive wheel in the case B to pass on to actuate the second wheel in the case B^{11} the better to utilize its force and condense it into water, and thence pass round the return pipe F back to the inducing steam injector A^1. The water from the condensed steam being trapped by the annular trap F^4 passing down through the branch pipe F^3 into the cistern E. The two spindles D, D^{11}, of the motive wheels are geared together to the cross shaft D^{111}, which by the three cog wheels indicated by the dotted circles D^3, D^4, D^5, the cross shaft D^{111} being used as the connection for giving out the power of

the combined engines. The same letters of reference refer to the same parts as in Figures 1 and 2, and the direction of the motion of the wheels, and course of the steam, water, and air currents are as indicated by the arrows.

Figure 10 is a sectional side elevation, and Figure 11 an end elevation partly in section, of a motive-power engine, to be actuated by this improved return mode of utilizing the force of steam having a motive wheel similar to an ordinary inward flow water turbine or water wheel. The steam is admitted by a branch pipe connection A to an annular steam inducing jet nozzle A^1 similar to that described in connection with Figures 1, 2, 3, and 4, with slight modifications at the point of the inner casing at *a* to direct the current of motive vapour through the conical annular casing A^{1111} into the motive wheel case B at the annular space B^2, B^2, between the periphery of the motive wheel C and the inner circumferential surface of the case, and thence inwards to the centre of the wheel through the curved vanes *c* of the motive wheel, as indicated by the arrows seen in Figure 11, and thence again passing from the centre of the motive wheel C through the central return channel F to be induced back through the annular channel A^{1111} and on through the motive wheel again, as indicated by the blue arrows and darts, the waste steam escaping by the central orifice or pipe or branch pipe piece F^1, and the water from the condensed steam passes down through the branch B^3 of the case B of the wheel down through the branch pipe E^1 to the water cistern E, from which it is fed away to supply the boiler or steam generator. The motive wheel C is keyed on the spindle D, which works in the bush bearing B^1 formed or fixed on the side plate B of the case and the bush bracket D^1. The conical piece C^{1111} which forms the inner surface of the annular induction channel A^{1111} and central return channel F is composed of thin plates, and is fixed upon and revolves with the motive wheel C. The power of the engine may be given off by a belt pulley D^2 or by cog wheels or other gear. Where the parts are similar the same letters refer to the same parts as in Figures 1 and 2, and the direction of the motion of the currents are all as indicated by the arrows.

Figure 12 is a sectional side elevation, and Figure 13 an external elevation of a similar motive-power engine to that described in connection with Figures 10 and 11 with only some different details for causing it to reverse. The same letters refer to the same parts in each,

and the same description answers for both except these reversing details, which I shall describe. The inducing annular steam nozzle A^{1}, A^{11}, is formed double, having corresponding steam branch pipe connections A and A*, which are joined together with the three-way steam cock A^{111}, which by turning the key handle shown turns on the steam to either steam branches A or A*. When the steam is turned on to the branch steam pipe A and thereby caused to issue from the annular nozzle *a*, the direction of the current of steam or vapour is as indicated by the arrows, and the motion and action similar to that described by Figures 10 and 11. On the steam being turned into the steam branch pipe A* it issues from the annular nozzle *b*, and sends the current into the centre of the turbine and out through the vanes *c* in the manner of an outward-flow turbine, and thence round the conical and annular channels B^{2}, A^{111}, thus reversing the motion of the motive wheel C. The inner conical surface and piece of these channels C^{111} does not in this modification revolve with the motive wheel C, and the waste steam escapes by the central waste pipe F^{1}.

Figure 14 is a side elevation, partly in section, Figure 15 an end sectional elevation through the line *a*—*b* in Figure 14, and Figure 16 an external end elevation of a motive-power engine, to be actuated also by the same form of a steam inducing annular nozzle to induce in the waste or return steam from the exhaust port of the case, having a reaction motive wheel or mechanical motor similar to the well known water wheel known as Whitelaw's water wheel, the construction of this wheel will be readily understood from the sectional Drawings. The same letters of reference indicate similar parts or parts serving the same purpose as in Figures 1 and 2. The steam is admitted from the boiler to the steam branch pipe A and the annular jet nozzle A^{1}, and issues into the centre of the motive wheel C, and thence issues out at the two jet nozzles *c*, *c*, in the periphery of the wheel C, indicated by the arrows in Figure 15, causing the motive wheel to revolve by the reaction of the issuing jets of steam, which then flows into the case B, and passes out by the connected return pipe F round, as indicated by the arrows, back to the annular inducing jet nozzle A^{1}, and induced in by the jet of steam, and sent through the motive wheel C again. The condensed water being trapped by the trap F^{4}, is directed and led down through the pipe F^{3} into the water cistern E, the waste steam, or such a portion of the steam as the inducing

jet nozzle does not induce and send through the motive wheel again, passes out by the waste pipe F^1, and the course of the currents are as indicated by the arrows. Although I have shown only one form of inducing jet nozzle for taking in exhaust steam or air along with the steam from the boiler, mainly that of the annular form and jet, which I prefer as the best, yet still other forms of jets will serve the same purpose. And Figure 17 is a sectional side elevation, and Figure 18 an end elevation of a modification, in which the pipe A leads in the steam from the boiler, and issues it in the form of a cylindrical jet from a conical nozzle A^1 in the centre of the large pipe A^2, which admits the cold air at A^{11} by the sliding valve piece A^3, as indicated by the yellow arrows, while by the branch pipe F the return steam is induced and forced through the pipe A^4, as indicated by the blue arrow.

Figure 19 is a sectional side elevation, and Figure 20 an end elevation of another form of inducing jet nozzle to be used for these return steam motive-power engines, in which the pipe A admits the steam from the boiler and is formed at its extremity into a cylindrical jet piece A^1 within the nozzle piece A^2, as in the previous modification. The branch pipe A^{11} admits the cold air when required, controlled by a valve A^3 and the pipe F the return steam, the combined current passing out by the pipe or channel A^4, as indicated by the blue arrows. Where great power and slow angular motion is required in the motive wheel large diameters are necessary, and in such cases a large cylindrical drum or motive wheel with angularly placed or curved vanes fixed upon its periphery, and steam or vapour passed along these vanes in a parallel direction to the axis of the motive wheel in a correspondingly large jet or current, will produce this result.

On Sheet 5 of my Drawings Figure 21 is an end elevation partly in section, Figure 22, for the most part, a sectional side elevation through the line *a—a*, in Figure 21; and Figure 23 an external plan of a motive-power engine of this description. A steam pipe A, from a steam boiler or generator leads the steam to an annular jet nozzle A^1, into which the return steam current jet pipe A^2 is entered, fitted with the annular sliding valve piece A^3 for regulating the annular opening A^{11} for the admission of cold air, and the nozzle piece A^1 is connected to the motive wheel case B at the induction port B^4 of the motor. A portion of the end plate of the case B is shown broken off in Figure 21, and a portion of the periphery plate B^2 of the case B on the line *a—a*, Figure 23,

to show the form of the motive wheel, which is made of one casting, with sets of arms C^2, C^2, and centre C^1 at each end of the rim plate C^3, from which the curved obliquely set vanes *c*, *c*, *c*, project; a portion also of the rim plate C^3 being broken off to show the arms and rim plate C^3 in section, with the full breadth of one vane *c* in its position when placed in line with and between the induction port B^4 and exhaust port B^5 in the case. The motive wheel C is keyed upon the spindle D, and made to run truly in the bushes B^1, B^1, fixed in the ends of the case B and bush bracket D^1, and having a pulley D^2 keyed upon it for giving off its power by a belt, the motive wheel C and its vanes *c* being made to revolve freely and out of contact with the case, accurate fitting not being necessary. The exhaust port B^5 has connected to it the pipe F for conveying the exhaust steam to the branch pipe F^3, having a water trap F^4 and branch F^2 for carrying down the condensed water and waste steam to the cistern E, the exhaust or return current pipe F being from the water trap F^4 thence carried round and terminating in the return current jet pipe A^2, as explained. A condensed water pipe B^3 and E^1 conveys the water from condensation in the case B to the cistern E, and a pipe G is connected to the cistern for leading away the water to the steam boiler or generator, and the cistern also has connected a pipe E^2 for conveying away the waste steam. Thus arranged, and steam being made to enter by the steam pipe A, a current is caused to pass in a straight line across the periphery and between the vanes *c*, *c*, *c*, of the motive wheel C from the induction port B^4 to the exhaust port B^5, and round the return pipe F, the current impinging on the after sides of the vanes and causing the wheel C to revolve, the motion of the motive wheel being as indicated by the arrow on the end of the case B in Figure 21 at *c*, *c*, and the course of the fluid currents as indicated by the blue, yellow, and black arrows. The guiding or "louver board" plates *b* in the induction and exhaust ports for retaining the current in direct line are placed vertically in this modification, as seen in Figure 23 by the dotted lines *b*, *b*, *b*. It will be readily understood that various modifications can be made of this form of motive-power engine to be actuated by return steam currents; and two or more sets of ports can be formed in the case, or annular ports all the diameter of the case, and the vanes of the motive wheel may be formed so short as to resemble the vanes of a windmill. In using steam from a common steam boiler for these return steam current motive-power engines the steam and return steam or vapour, before it reaches the motive wheel, may be super-

heated and increased in volume and force in a vessel or tapering channel or pipe, by the pipe being led through the waste heated gases passing from the boiler flue or fire-box to the chimney.

Figure 24 is a plan, and Figure 25 a sectional elevation, showing the jet pipe A^4 passed through the fire-box I^2 of an ordinary vertical dome boiler I and flue I^{11} leading to the chimney, controlled by a damper I^3 between or in its passage from the jet nozzle piece A^1 and the induction port B^4 of the motive wheel C. This motive-power engine is otherwise nearly identical with that described in connection with Figures 1 and 2 on Sheet 4 of my Drawings, and the same letters refer to like parts and therefore need not be here further described. The course of the currents are as indicated by the arrows; and the current in the jet pipe as it passes through the flue I^{11} and fire-box I^2 is expanded and correspondingly intensified in force. The steam current also may be expanded by direct contact with the heated gases in the furnace by having a portion of the jet pipe A^4 formed similar to that shown in Figures 23 and 24 on Sheet 1 of my Drawings; or portion of the gases may be induced into the pipe by an inducing jet nozzle A^4, as shown in section, Figure 26, which represents a part of the boiler I where the pipe A^4 passes through it; or the jet nozzle pipe A^4 may be formed with a number of openings *d*, *d*, *d*, as shown in section in Figure 27, by a similar portion of the boiler I and jet pipe A^4; the course of the currents are as indicated by the arrows. Where any considerable portion of the waste gases or gases of combustion are induced into the jet pipe A^4, as explained, correspondingly large waste pipes, F^3, F^2, and E^2 have to be provided. In another form all the waste gases and heated air may be induced in along with the steam into the motive-power engine to actuate it, and thereafter returned in a circular channel having its concave side open for the return or exhaust vapour or gases to come in contact with the atmosphere for the absorption of oxygen or fresh air; a portion of the heated current thus returned is sent through the boiler or steam generator furnace to support the combustion of the fuel, and the water from the condensed vapour trapped and led off for the supply of the boiler or generator.

Figure 28 is a sectional side elevation, and Figure 29 an external end elevation of a Cornish boiler having a motive-power engine fixed upon the top of it, adapted to be actuated by a return current of vapour in this way, the motive wheel C and all the parts of this engine being

similar, and correspondingly lettered to that described in connection with Figures 1 and 2 on Sheet 4 of my Drawings, need not be here further described than in reference to the parts of the apparatus for maintaining and regulating the currents peculiar to this modification of my said Invention. Steam is conducted from the boiler I through the vertical steam pipe A to the annular jet nozzle A^1 connected to the induction port B^4 of the engine, and a cock a^1 and pipe a^2 connected to the boiler and bent downwards leads steam to an annular jet nozzle a, similar to the other jet nozzles A^1, connected to the boiler underneath the furnace, and to which the return pipe or channel F is connected. The boiler I is provided with tight furnace and ash-pit doors G, G, and at the back end of the flue G^{11} to that of the furnace I^2 a mouth casting G^{111}, to which the forcing pipe A is connected, terminating in the bent jet or forcing pipe A^2. The return current pipe F from the part F^5 to the part F^6 is formed open on the under side, the transverse section of this part being as shown drawn to a larger scale in Figure 30, the space a, b, being open to the atmosphere, and to prevent the condensed water which adheres to the surface of the channel or pipe from dropping out small "rone" channels g and g^1 are formed in it; the return pipe being thence continued on to the annular jet nozzle A^1 a, underneath the boiler furnace, as shown and explained. A branch pipe F^2 traps and leads off the condensed water to the cistern E, which is provided with a branch pipe G for leading away the condensed water to the boiler and a waste vapour pipe E^2; thus arranged and the steam from the boiler being admitted to the steam pipes A and a^2 the motion of the currents are as indicated by the arrows, and motion of the motive wheel C as the arrows placed upon it. The mixed steam and gases become greatly expanded in the furnace I^1 and flue G^{11} and form a highly expansive vapour at a moderate pressure and in great volume, which inducing cold air at the opening A^{11}, and all impinging against the vanes of the motive wheel C, causes it to revolve, the pipe F carrying it back again with its oxygen partially restored to it in passing through the open channel F^5 to F^6 by exposure to the atmosphere, and its centrifugal force in passing round the curve retaining it, or most part of it, in its course. Whilst the return mode of utilizing the force of steam or vapour as described can be wrought with advantage by steam or vapour from an ordinary boiler, it is also intended to apply and use the steam or vapour generator described under the first head or section of this my said Invention for generating vapour to work these return

current motive-power engines; portion of the waste gases to be returned to the generating channel or to the furnace, or portion of the exhaust vapour can be returned and re-induced to the motive wheel along with the vapour from the generator.

Figure 31 is a sectional side elevation, and Figure 32 an end elevation of a similar motive-power engine to that just described, but instead of a Cornish boiler being used for generating steam a vapour generator with duplex furnace I and heating channel D^3 with angular "louver"-formed recesses *d*, *d*, *d*, is employed for generating the actuating motive fluid current much similar in construction to that described in connection with Figures 51 and 52 on Sheet 3 of my Drawings, and the generator therefore need not be again described. The motive-power engine, all except that the annular jet nozzles A^1, A^1a, are dispensed with, are the same as that just described in connection with Figures 28, 29, and 30, and the same letters of reference refer to similar parts, and therefore does not require other explanation. The motion of the motive wheel C is as indicated by the arrows upon it, and the motion of the currents is as indicated by the black and coloured arrows and darts. This return mode of utilizing the force of steam can be applied with advantage to cylinder engines with reciprocating pistons, and in one form by connecting the induction steam ports and passages to the cylinder, and having an annular space formed in the centre or at some intermediate point in the passage, with a tubular valve piece or annular jet nozzle at this space, and the steam regulated so as to direct the current by "tappet," eccentric, or other suitable valve motion, which admits the steam to the cylinder when the piston gets to the end of the stroke, for forcing it to the other end of the cylinder, whilst at the same instant it establishes a connection for causing an exhausting action on the opposite side of the piston. The steam or vapour, or what of it remains not condensed into water, is induced in and forced by the jet from the annular jet nozzle to the forcing side of the piston; as the motion of the piston and connecting rod traverses, and as the crank and crank shaft goes round, the water from the condensed steam is trapped in the passages to a pipe or reservoir, the steam admitted into the cylinder bing sufficiently small in quantity to allow of the engine for the most part abstracting or utilizing in force such a proportion of heat as will condense it into water which can all, or nearly all, be returned to the boiler.

Figure 33 is an elevation partly in section, and Figure 34 a plan also partly in section, on Sheet 6 of my Drawings, showing a horizontal steam engine arranged to be actuated in this way. The sole plate, crank shaft, fly wheel, crank, and connecting rod are similar to the same parts in an ordinary high-pressure steam engine, and need not therefore be described; the steam cylinder and immediate parts, which are large in proportion to the other parts of the engine, so as to act by a low pressure of actuating vapour, only requiring description. On steam being admitted from the boiler to the pipe and cock or valve A and to the casing J, to produce motion on the piston in the direction of the arrow 1, the slide valve e is moved by the eccentric e^2 on the crank shaft, until it admits steam through the passage e^1 to the annular jet nozzle A^1, which induces the exhaust steam from the exhaust or other side of the piston, causing it to pass through the passage or jet pipe A^7, and sends it along with the steam from the boiler through the jet pipe A^4 and port B^4, the water from condensation being trapped by the annular trap F^4 and diverted down by the pipe F^2 to the cistern E. When the piston in motion in this direction gets to the end of the stroke, the eccentric e^2 on the crank shaft has moved the slide valve e until the steam is allowed to pass through the passage e^{11} into the annular jet nozzle a^1, which is set in the opposite direction to that of the nozzle A^1 and induces out the steam from the cylinder through the port B^4 and jet pipe A^4, as indicated by the blue darts on it, and sends the current through the jet pipe a^4, as indicated by the blue arrow placed on it, through the induction pipe b^4 at the opposite end of the cylinder B, and thus giving motion to the piston in the opposite direction or that indicated by the arrow 2. When the current is in motion in this direction the water from the condensed steam is trapped by the annular trap F^4, and led by the branch pipe F^2 into the cistern E, the water from the cistern E being led away by the pipe G to the boiler. A pipe E^2 is connected to the cistern E to lead away the waste steam that passes down through the branch pipes f^2 and F^2. The motion of this engine is otherwise similar to that of an ordinary steam engine, the eccentric on the crank shaft giving motion to the slide valve e so as to open and close the passages at the required positions of the piston, and give continuous action as in ordinary high-pressure steam engines. Besides being thus suitable for reciprocating crank engines, a useful modification for utilizing the force of steam in this way is obtained by long cylinders for working hoists and other similar machines with

the motion wrought by hand for producing a single traverse or stroke of the piston at a time.

Figure 35 is a sectional elevation of this arrangement, and as the cylinder and all the parts are exactly similar to that described in connection with Figures 33 and 34, and the same letters of reference referring to like parts, the description given in connection with these is sufficient, the only difference being that instead of the slide valve *e* being wrought by an eccentric it is in this case adapted to be worked by hand. The piston rod of the cylinder is shown fitted with a chain for working over pulleys in the ordinary manner of piston hoists.

The essential, new, or improved feature of this part of my Invention consists in returning the steam from the exhaust side of the motive wheels or pistons in such a way as to cause a portion of it to be induced by a jet of steam in over again or afresh, by the inducing jets of steam from the boiler or vapour generator to propel a motive-power engine; and in combination with this the means for trapping the condensed water for supplying the boiler or steam generator.

Another improvement under the second head or section of this said Invention consists in mechanism for working motive wheels and turbines by steam and air combined or mixed by direct single currents, or a current only once passed through or over the vanes of an impelled motive wheel or turbine, the motive wheels with their cases being essentially of the same construction as those described in connection with Figures 1 to 16 on Sheet 4, and Figures 21 to 32 on Sheet 5, of my Drawings, and the same letters of reference refer to like parts in these Figures.

Figure 36 is a side elevation partly in section, and Figure 37 an external end elevation of a motive-power engine similar to that described in connection with Figures 1 and 2, on Sheet 4 of my Drawings, but in place of the return steam pipe F being connected to the exhaust port of the motive-wheel case, as seen in these Figures, I attach to the exhaust port B^5 of the motive-wheel case (Figures 36 and 37, on Sheet 6 of my Drawings) an expanding throat, conical, or trumpet-shaped pipe F for carrying off the waste steam and air current after it has passed from the motive wheel of the engine. On steam being admitted from a steam boiler or generator by the steam pipe A to the annular jet nozzle A^1 a large quantity of cold air is induced in at the central opening A^{11}, and passes combined with the steam through the jet pipe A^4, and

induction port B^4, and between the "louver boards" or guiding vanes *b*, *b*, *b*, in the port B^4 in thin streams or jets so as to impinge against the vanes *c*, *c*, *c*, of the wheel C, and give motion to it in the direction of the black arrow placed upon it at *c*. The current is also exhausted from the vanes of the wheel in thin streams in the exhaust port B^5, and from thence passes into the expanding throat pipe F, which produces after the current is started an exhausting action, and its increased area at the discharge, or where it may enter another channel, causes the current to escape with little force or back pressure on the vanes of the wheel. Where practicable this pipe should be prolonged in the tangential line of the induction and eduction ports B^4 and B^5, in length about ten times its diameter at the exhaust port B^5, and its sectional area at its extremity should be about four times its area at its junction with the port B^5; the same exhausting action will be more or less obtained by bending it upwards or otherwise as indicated by the dotted lines if its trumpet form be preserved, but the straight form as described acts with most advantage.

Figure 38 is an elevation partly in section, and Figure 39 a sectional side elevation, of a motive-power engine also adapted to be actuated by mixed steam and air passed once through the motive wheel C; the form of this motive-power engine is with slight modifications that of a upward flow turbine, and similar to that described in connection with Figures 12 and 13, on Sheet 4 of my Drawings, when it is there acting as an outward-flow turbine; the same letters also refer to like parts, and need not be here again described. On steam being admitted by the pipe A to the annular jet nozzle A^1, the motion of the currents is as indicated by the coloured arrows, the motion of the motive wheel C being as indicated by the arrow on the case in Figure 38, and the exhaust vapour after it has passed through the wheel C escapes by the trumpet-shaped pipe F connected to the turbine wheel case B.

Figure 40 is a side elevation partly in section, and Figure 41 an end elevation of a motive-power engine, also adapted to be actuated by mixed steam and air; the form of the motive wheel in this engine is the same as that known as Whitelaw's water wheel, and all its parts are similar to that described in connection with Figures 14, 15, and 16, on Sheet 4 of my Drawings, except that I have in this modification (Figures 40 and 41), connected to the case B the trumpet-shaped exhaust pipe F; the same letters indicating the like parts in these Figures, and therefore

this motive engine need not again be described. The direction of the currents is as indicated by the coloured arrows, and the motion of the motive wheel by the arrow on the case B in Figure 41. In these modifications of motive-power engines described in reference to the Figures on Sheet 6, to be actuated by direct currents of steam and air passed once over or through the motive wheel, the annular steam inducing nozzle A^1, the guiding plates or "louver boards" *b*, *b*, *b*, (in the induction and exhaust ports B^4 and B^5, whereby the current is led on and off the impelled motive wheel,) and the exhausting trumpet-shaped pipe F are the novel and essential features in this part of my Invention. The jet or current pipe A^4 may be formed long for the transmission of power to long distances, as steam and air mixed in this way does not condense readily.

Figure 42 is a side elevation partly in section, showing a motive-power engine similar to that described in connection with Figures 36 and 37, but besides being adapted to be actuated by steam and air mixed as there described, this modification is also adapted to be in part actuated by waste gases from a furnace, induced in among the steam and air in motion to rarify and expand the current, and to increase its volume and force, the temperature of the waste gases from a boiler furnace being much higher than steam and air alone mixed in this way. A vertical dome boiler I of the ordinary description is shown in section connected to this motive-power engine with the internal fire-box I^2, having the funnel I^{11} led direct to the centre of the annular steam jet inducing nozzle A^1, the funnel I^{11} being also continued upwards for carrying away the gases when the engine is not in action, and provided with a damper I^{111}, for closing when the heated gases are wanted for the engine. The horizontal flue part of this funnel I^{11} is shown contracted into a jet pipe A^2, about one-third part smaller in diameter than the internal diameter of the annular steam inducing nozzle A^1, and of its pipe A^4, and is led past the issuing annular steam jet of the nozzle A^1, as shown; the cold or atmospheric air therefore is first induced in by the annular steam jet through the annular opening or channel A^{11}, and the current thus formed induces in the heated furnace gases at a point beyond the steam annular nozzle A^1, causing increased expansion and force of the whole motive fluid, which passes in through the induction port B^4 of the motive wheel C, and impells it round in the direction indicated by the arrow placed on the case B, the exhaust current

passing out by the trumpet-shaped pipe F, all as indicated by the coloured arrows. The annular steam jet nozzle A^1, current guiding or "louver board" plates *b*, *b*, *b*, in the induction and exhaust ports B^4 and B^5, and the exhausting trumpet pipe F, together with the arrangement for introducing the waste gases at a point in the jet or current pipe A^4 beyond the annular steam jet nozzle A^1 are the novel and essential improvements or features of this part of my Invention. The course of currents is as indicated by the coloured arrows. Instead of the heated gases from the furnace being induced in through the centre of the steam nozzle A^1, by the jet pipe A^2 as described in connection with Figure 42, the heated gases may be induced in at the branch pipe A^2 *b*, and the whole of the area A^{11} of the centre of the steam nozzle A^1 left for the induction of cold air.

Figure 43 is an elevation of this arrangement of nozzle A^1 and current pipe A^4, with a branch pipe A^2 *b*, and annular nozzle opening a^{11} for the induction of the heated gases from the furnace, the arrangement of the steam nozzle A^1, ports B^4 and B^5 in the case, and trumpet exhausting pipe F being the same as described in connection with Figure 42; the course of the currents being as indicated by the coloured arrows. Instead also of the cold or atmospheric air being induced in through the centre of the annular steam jet nozzle A^1 first, as described in connection with Figures 42 and 43, I also induce in the heated gases from the furnace through the centre of this form of annular steam inducing nozzle, and thereafter induce in the cold air to be expanded by the combined steam and heated gases.

Figure 44 is an elevation of an annular steam nozzle A^1, and current pipe A^4, in which the heated gases are admitted by the end orifice marked A^2 *b* and the branch pipe and nozzle used for the induction of the cold air, marked in this Figure A^{11} and a^{11}; the same arrangement for the conveyance of the current through the ports B^4 and B^5, with guiding plates *b*, *b*, *b*, and exhausting trumpet pipe F, being with these retained as the essentially new features of this part of my Invention. Although also I prefer to use the annular steam inducing jet nozzle A^1, yet with my other improvements of the induction and exhaust ports B^4 and B^5, and "louver boards" or guiding plates *b*, *b*, *b*, in these ports, and trumpet exhaust pipe F, I also use a small cylindrical steam jet inducing nozzle A^1 (in lieu of the annular nozzle A^1), similar to that described in connection with Figure 17 on Sheet 4 of my Drawings;

the heated gases to be induced by the branch pipe A^{11}, instead of exhaust steam by the branch marked F, as there described. The modifications of motive-power engines as described in connection with Figures 1 to 16, on Sheet 4 of my Drawings, and Figures 21 to 24, on Sheet 5 of my Drawings, are with the modification of the motive current pipes suitable to be actuated in this way with simple direct currents of combined steam, atmospheric air, and heated gases passed once over or through their motive wheels C, and may have several pairs of induction and exhaust ports B^4 and B^5, as described in connection with Figures 5 and 6, or be caused to reverse their action as described in connection with Figures 7 and 8, on Sheet 4 of my Drawings.

Another improvement under this second head or section of my said Invention consists in a mode of transmitting power and actuating pistons or other equivalent motive parts of motive-power engines, or rotating wheels or turbines, already in part described in connection with this second head or section of this my said Invention. By exhausting pure or atmospheric air in through these motive-power engines by the exhausting action of inducing injectors, produced by the same means and apparatus as herein-before described for generating and directing currents (under the first and second heads of my Invention), the construction of the motive-power engines being similar to all those described in connection with the foregoing second part of this Invention, but in some cases the motive wheels require no enclosing cases, the surrounding air flowing inwards to the turbine motive wheels, and causing them to revolve; power may in this way be transmitted to great distances in mines, factories, and warehouses, and at the same time exhaust away the surrounding air, and tend to promote ventilation.

Figure 45 is a side elevation partly in section, Figure 46 an external pan, and Figure 47 an end external elevation of exhausting ejector, and one modification of a turbine, with the pipe connections to show how this mode of transmitting power may be carried into effect. Where there is a number of motive-power engines to be actuated from one main exhausting pipe, I prefer to use a corresponding number of small steam ejectors, instead of one large one, as in cases where one or more of the engines to be actuated might require to be at rest, a waste of steam would be incurred while part only of the engines were at work. A steam pipe A conveys steam from a steam generator to the two steam annular jet inducing nozzles A, A^1, which are similar to those described

in connection with Figures 3 and 4 on Sheet 4 of my Drawings, the steam to each being regulated by a stop-cock A^{111}, the action of which exhausts the air from the main exhaust pipe F^7, and ejects it through the trumpet-shaped pipes F, F, which are similar to that described in connection with Figures 36 and 37, which increases the effective action of the ejectors. Where the steam is generated by a common steam boiler the effective exhausting action may also be increased, and the fuel required for the boiler be economised by inducing in the waste heated gases from the furnace by the pipe I^3 and the waste gases jet pipes A^2, A^2; the exhausting action of the steam jet nozzles A^1 causing a partial vacuum in the main pipe F^7, into which, where there is an opening formed at any point, the atmospheric air will flow in with considerable force. A turbine wheel C, of the Whitelaw water wheel form, and similar to that described in reference to Figures 40 and 41 without the case B, is shown as fitted to the pipe F^7, the air flowing inwards instead of outwards through the jet openings *c* of the wheels C, into the pipe F^7, as indicated by the yellow arrows, causes it to revolve in the direction of the arrow placed upon it. The spindle D of the turbine wheel C has a band pulley D^2 keyed upon it, and in Figure 45 a band D^3 is shown carried up to a pulley D^{111}, through which the power of the wheel C is transmitted to the shaft of the pulley D^{111}, or other equivalent gear applicable for transmitting the power, as circumstances may require. Any of the modifications of motive-power engines described on Sheet 4 of my Drawings in connection with Figures 1 to 16, on Sheet 5 described in connection with Figures 21, 22, and 23, and on Sheet 6 in connection with Figures 33, 34, and 35, are all with slight modifications suitable for being actuated by exhausting action in this way.

For working warehouse hoists an arrangement of cylinder similar to that described in connection with Figure 35 will with slight modifications be suitable, but large area for such purposes being required, and accurate fitting not being necessary, a square form of reciprocating engine will be found suitable, fitted with a piston, and may be composed of plates of metal or planks of wood.

For coal mining, quarrying, and similar purposes where portable motors are required, the connection may be obtained by a flexible hose pipe and applied to light boring purposes, such as for working a drill.

Figure 48 shows a light turbine made of light tin plate, and similar to that described in connection with Figures 45 and 46, the spindle D of

which is here shown fitted with a drill D^4, and ports *c* of the wheel C being left open to the atmosphere.

Figure 49 shows a light portable cylinder B adapted to have a piston and rod actuated for working a "jumper" drill D and D^4, the exhausting action being regulated by hand by the valve A^5 and handle A^6 which is similar to the working valve of a steam hammer, the piston and drill being raised by the exhausting action above the piston in the cylinder B, and the descent caused by the valve being closed to the pipe F^9 and open to the atmosphere, to allow the piston and drill to fall by their gravity; a handle D^{111} being provided to turn round the jumper drill D.

The essential, new, or improved feature of this part of my Invention is the employment of steam inducing ejectors as described, to actuate motive-power engines by exhaustive currents or jets; though I prefer the annular steam inducing jet nozzle A^1, as described, as the most efficient for this purpose, yet I may use any of the forms of inducing jet nozzles described on Sheets 1, 2, and 3 of my Drawings for this means of transmitting power by exhausting atmospheric air, as described.

Another mode or means of applying the improvements under the second head of this my said Invention consists in actuating motive-power engines by heating water and generating steam in a boiler similar to the process of generating steam for a steam engine, but instead of the steam being taken or led in pipes to expand and transmit its force to a piston, or any impelled equivalent, I draw or take off the water in the boiler to propel or actuate engines, returning the same again to the boiler in a continuous or approximately continuous stream; the steam generated in the boiler to be led off to an injector at or near the ingress end of the water return pipe to the boiler, to induce and force back the water into the boiler, and by the action of the steam in this way maintain the continuity of the impelling water current. Wheels or turbines similar to those used generally as water-power engines, connected to and between the egress and ingress end of the water pipe from and to the boiler, are suitable as motive wheels for taking the power from the water in motion; by these means and by suitable means for regulating the returning currents reciprocating piston motive-power engines under some circumstances and conditions can also be advantageously actuated in this way.

On Sheet 7 of my Drawings, Figure 1 is an elevation showing all the working parts in section, and Figure 2 an external plan, showing an ordinary vertical dome, and internal fire-box boiler, having a funnel from the side of the fire-box to convey away the smoke and waste gases, safety valve, and the ordinary mountings for a steam engine boiler, and arranged to actuate a motive wheel by water from the boiler, as described, the motive wheel with its case and parts being similar to that described in connection with Figures 1 and 2, on Sheet 4 of my Drawings. A steam pipe A, conveys steam from the boiler to an annular inducing jet nozzle A^1, similar in construction to that described in connection with Figures 3 and 4, on Sheet 4 of my Drawings, the steam pipe A having in it a regulating stop-cock A^{111}. The water pipe B is fixed and jointed in the top of the boiler, descends down into the boiler below the water line, and is carried round and down as shown, and connected to the induction port B^4 of the motive-wheel case B^2, and the return pipe F is connected to the exhaust port B^5 of the motive-wheel case B^1, and carried down, round and up, in an ascending direction, so as to join the annular inducing jet nozzle A^1. The ascending part of the returning water pipe F being provided with a cylindrical jet nozzle F^1, to which the boiler feed water pipe G and regulating stop-cock G^1, is connected. The annular jet nozzle piece A^1 is carried forward and terminated in the cylindrical jet nozzle A^3, inside a waste steam and water chamber F^2, which is provided with a branch pipe F^3, to which a closing cock E and steam and water pipe E^1 is connected and continued on to discharge the waste water and steam into the cistern E^{11}. The waste steam and water chamber F^2 is provided with an expanding throat channel F^4 proportioned to the area of the jet nozzle A^3, and is set in line and opposite to it. This throat channel F^4 has cast on its top end a valve chest F^5, which has fitted in it the two self-closing and opening hinged valves f and f^1, the ascending return pipe F^6 being connected to this chest, and ascending up through the centre of the boiler fire-box I^2, as shown, and enters and is jointed in the centre of the crown of the fire-box plate, and terminated in a jet nozzle F^7 opposite the bell mouth of the forcing or eduction water pipe B, the water from the boiler being prevented from passing down through the pipe E^6, by the self-closing valves f and f^1. To cause the water to circulate, to assist the action of the upward current, an annular shell plate H, H, is placed in the centre of the water space between the fire box plate

and the outer shell plate, which has the well known effect of causing a current of water to pass downwards close to the comparatively cold outer shell plate, as indicated by the arrow, and an upward current close to the fire-box, as indicated by the arrows, and thereby gives a circulating motion in the direction of the current required for the water passing out at the mouth B^{11} of the eduction pipe B, and slightly assists the action of the inducing annular steam jet nozzle A^1. Thus arranged and steam generated in the boiler, and the steam cock A^{111} opened, as also the feed water cock G^1 and waste steam and water cock E the water from the boiler ascends up through and round the pipe B to the induction port B^4 of the wheel case B^2, giving motion to the motive wheel C, and passing from the exhaust port B^5, in the motive wheel case, enters the return pipe F, and round, up, and into the annular steam inducing nozzle A^1, as shown, getting its motion greatly accelerated by the steam, and thence issuing from the jet nozzle A^3 passes up the throat channel F^4, and starting up the valves f and f^1, ascending up the pipe F^6, enters the boiler, and issues from the jet nozzle F^7, and in this way courses round the pipes as indicated by the black arrows, and gives motion to the motive wheel C, as indicated by the arrow on the case B^2.

Figure 3 is a sectional side elevation, and Figure 4 an external end elevation of a similar motive-power engine impelled by water, a common Cornish boiler I being employed to generate steam to induce back the water and contain the necessary volume of water for circulating through the pipes and for the generation of steam. Except in the form of boiler used, and in the disposition of the pipes, there is no substantial difference in this engine from the one last described, in reference to Figures 1 and 2, and the same letters of reference indicate the same or like parts in this modification as in the previous, and therefore further description is unnecessary, the slight differences being evident from the Drawing. Instead of the cylindrical jet nozzle F^1 for admitting the feed water employed in Figures 1 and 2 an annular jet nozzle F^1 is here used; the arrangement of this feed water nozzle will be better understood from the enlarged external plan Figure 5, and sectional elevation of it shown in Figure 6, the feed water is admitted to the annular space of the nozzle F^1 by the water pipe G, and the steam admitted to the annular space of the steam jet nozzle A^1 by the branch pipe A. By this arrangement

there is an outer or thin surrounding stream of cold water injected into the main stream, coursing through the pipes, which, by its close proximity to the steam nozzle A^1, does not get time to be raised to the same temperature as the water in the centre of the moving water column, until it reaches the steam from the annular jet nozzle A^1, and in this way secures greater condensation and better motive effect and absorption of heat, from the steam, than if the water were admitted by a cylindrical jet, as described in connection with Figures 1 and 2. The course of the currents and motion of the motive wheel in this engine (Figures 3 and 4) are as indicated by the arrows.

Figure 7 is an external elevation, and Figure 8 an external plan of a common vertical dome steam boiler, similar to that shown in section in Figure 1, employed to actuate a reciprocating piston motive-power engine B^2, the arrangement of which will hereafter be described on Sheet 12 of my Drawings. The impelling water current is led in this example near to the bottom of the boiler I by the pipe B direct to the motive engine, and is shown fitted with a regulating stop-cock, the return current pipe F ascending up to an equalizing chamber F^s, into which the returning water first enters before it passes down through the steam inducing injector and injecting throat pipe. The object of this regulating chamber F^s is to recieve the intermittent discharges of water from the reciprocating engine B^1; and as there will always be steam or vapour, more or less elastic, vapour will collect in the top of the chamber F^s, and thereby act like an air vessel in the forcing pipe of a forcing pump, and so tend to equalize the jet passing down through the nozzle A^3 and throat pipe F^4 into the boiler. By this or similar means of rendering the exhaust current from reciprocating engines continuous or approximately so, it is intended to give motion to this or any ordinary form of water engine. As the injector pipes and other parts are otherwise the same in this engine as those described in connection with the foregoing Figures on this Sheet, and the same letters of reference referring to like parts, it does not require further description.

Figure 9 is a sectional elevation, and Figure 10 an external plan of a similar common vertical dome boiler to that described in connection with Figures 1 and 2 and 7 and 8 on this Sheet, with the same or similar arrangement of steam and water pipes with a return water inducing injector arranged to work a water ram B^3 working in a cylinder B^2, having a chain pulley fitted on the bottom end of the cylinder, and a

corresponding pulley on the top end of the ram for passing over the chains to increase its lifting traverse, being the common lifting ram and appliances of a hydraulic hoist, which need not be here described. To actuate this reciprocating ram B^3 the steam generated in the boiler I, and producing a consequent pressure on the water in it, the water is withdrawn from the boiler by the common three-way cock J, which allows the water to flow down through the water forcing pipe B into the cylinder B^2, and forces up the ram B^3; on turning round the handle J^1 of the three-way cock J the communication with the boiler is closed and a communication established between the pipe B and the return pipe F, and at the same time the steam cock A^{111} being opened the water flows out of the cylinder B^2, and allows the ram B^3 to return by its gravity or by the action of the resistance to the ram. The water flowing up the return pipe F through the returning injector A^1. As the arrangement and action of the pipes and injectors are otherwise the same as that described in connection with Figures 1 and 2, and 3 and 4, and the same letters of reference referring to like parts, this modification does not require other description. This arrangement for working rams and pistons for hoists and similar purposes, from the facility for regulating the motions and simplicity, has many advantages which hoists actuated by steam do not possess.

Figure 11 is an external elevation, similar to that shown in Figures 53 and 54 on Sheet 3 of my Drawings, showing an inducing injector A^1 and return pipe F connected to it. While these motive-power engines may as shown be connected to a common steam boiler and the water returned direct to the boiler, yet they may also be wrought by a separate vessel filled with water and steam or vapours, or as described in reference to Figures 53 and 54 on Sheet 3 of my Drawings, and the actuating or inducing steam either generated in a separate common boiler or by one of my steam or vapour generators described in connection with the first three Sheets of my Drawings.

The essential improvement or feature of novelty in this part of my Invention so far described in reference to the various Figures on Sheet 7 consists in withdrawing the water from the boiler or vessel containing water and steam under pressure, to actuate motive-power engines, and to induce or force back the water so employed to the boiler or water reservoir by a steam inducing jet or jets, any known effective form of

steam injector being available and intended to be used for returning the water to the boiler or reservoir.

Another part of my Invention under this second head or section, and somewhat similar to that last described, consists in mechanism for giving motion to water by steam injectors in a return stream or current to actuate turbines or motive wheels, or to give motion to a hoist piston by forcing action on one side of the piston and exhausting action on the other.

One modification consists in an endless annular pipe or channel, in which is cast on one side and somewhat less in diameter a case to receive a motive wheel similar to an undershot water wheel, the annular pipe or channel entering into and out of the case in a circular and unbroken course, motion being given to the water to actuate the water wheel by an inducing and forcing jet of steam or steam nozzle or injector.

Figure 12 is a side elevation, partly in section, and Figure 13 an external elevation of a motive-power engine arranged to be actuated in this way. The form of the motive-power engine B^2 used is similar to that described in connection with Figures 1 and 2 on Sheet 4 of my Drawings, which can be referred to. Steam is led from a boiler by the pipe A to the annular steam jet nozzle A^1, regulated by the steam cock A^{111}. To the discharge side of the steam injector A^1 is connected a segmental pipe B which, as shown, extends round and is connected to the induction port B^4 of the motive engine B^2; and to the exhaust port is connected the segmental return water pipe or channel piece F which is carried round, as shown, and connected to the inducing side of the annular steam jet nozzle piece A^1. The jet nozzle piece A^1, pipe B, portion of the motive wheel case B^2, and the pipe F forming a continuous circular or annular channel, into which the vanes of the motive wheel C are free to dip as it revolves. The return pipe F has cast on it a sole plate for forming a base for the engine, and is provided with a feed water branch pipe *e* for carrying away water to feed the steam boiler, a waste water branch and pipe E^1, and a water supply jet nozzle F^1 and pipe G. Thus arranged, and a small jet of water being made to enter by the jet nozzle F^1 until the annular channel and pipe channel B, B, and F, F, are filled, and thereafter steam admitted to the annular steam jet nozzle A^1 through the steam pipe A, motion is given to the water in the channel in an endless and returning stream, causing it to course through

the segmental portion of the motive wheel case B^2, between the induction and exhaust ports B^4 and B^5, and give motion to the motive wheel C by impinging on its vanes *c*. The quantity of water admitted by the jet nozzle F^1 should be such as will keep down the temperature of the water in the endless channel, the waste heated water being conveyed away by the waste steam pipe E^1. The centrifugal force of the current of water in the channel keeps the water out of the central parts of the motive-wheel case, and the height of the waste water pipe E^1 is regulated to give sufficient head to balance the centrifugal force of the water in motion. The motion of the engine and course of the currents are all as indicated by the black and coloured arrows.

Figure 14 is a sectional side elevation, and Figure 15 an external end elevation of a cylinder B^2 fitted with a piston B^3, arranged to be actuated by a return water current wrought by a steam injector. The piston rod B^3 and cylinder B^2 is fitted with pulleys for having a hoist chain passed over them, as described in connection with Figures 9 and 10, and this part need not again be described. A water pipe G conveys water to the small tank K, which has on its under side the branch pipe K^1, regulated by the trottle valve K^2, and admits water into the pipe F and cylinder B^2 until they are filled. In this state with water on both sides of the piston, on steam being admitted to the annular jet nozzle A^1, and the throttle valve K^2 closed, or nearly closed, and one at L open, the water is drawn out from the top side of the piston B^3 and forced into the under end of the cylinder by the injection nozzle A^1 until the piston reaches the top of the cylinder or any intermediate point, as may be required. On the steam being shut off from the injector A^1, and the regulating throttle valve closed, the piston and water in the cylinder will remain without motion, but on opening the throttle valve K^2 the piston will descend to the bottom of the cylinder by its own gravity, or be assisted by the action of the hoist chains over the pulleys, the throttle valve L or any equivalent valve affording handy means for regulating the motion of the piston B^3. The water tank K is provided with a branch pipe *e* for conveying the water in a hot state for feeding the boiler, in this modification, the heated water ascending up through the branch pipe K^1, and the cold water passing down alternately will keep the temperature of the water in the cylinder B^2 sufficiently low for the steam injector to act. The essential improvement or feature of novelty in this part of my Invention, as described in reference to Figures 12 to 15 on

Sheet 7, is the mechanism arranged to actuate motive-power engines by returning water currents essentially as described.

Another modification of carrying out the improvements under the second head of this my said Invention, consists in mechanism and modes for the utilization of waste heat or force from exhaust steam or vapour from motive-power engines by a current of air heated therefrom, which current is generated when in process of expansion from the heat utilized, the mechanism and modes being similar to some of the apparatus described under the first and second head of this my said Invention. A current of air may be caused to flow up through a conical or trumpet-shaped pipe or heater, as described in the first part of this Invention, for generating steam, the central flow of air to be allowed to mix with, or be kept separate from the steam or vapour or heating media. The heat or force may be utilized in two ways, first, by causing an exhausting or condensing action on the piston or equivalent motive parts of motive-power engines; and, second, by causing the air to be heated to flow into the boiler or steam generator furnace to support combustion or be caused to actuate an engine. Where the heated air is not so utilized, the exhausting or condensing action of the current of air may be increased by the waste gases being made to flow into the trumpet exhausting pipe to expand and increase the current of cold air entering at the exhausting end of the conical heater or exhausting pipe.

On Sheet 8 of my Drawings Figure 1 is a sectional elevation of an exhausting trumpet-shaped pipe or channel adapted for being coupled to the exhaust steam port of a cylinder reciprocating steam engine for causing a partial vacuum on the exhaust side of the piston. The apparatus is simply of a round form throughout in transverse section, except at the branch pipe connections, and therefore does not require a plan for its form to be easily understood. The exhaust steam pipe or port from the engine is connected to the branch pipe A which conveys the steam into the annular jet nozzle A^1, which is similar to that described in connection with Figures 16, 17, and 18 on Sheet 1 of my Drawings, but has in this case the central piece adjustable by a lever and extended down into an induction pipe B for the induction of cold air, the pipe B being moved up or down through the stuffing box B^1 by the hand lever B^2 so as to close or open to any required degree the annular jet nozzle opening A^1. To the jet nozzle piece A is connected

the trumpet-shaped expanding channel *c* which opens at the top out to the atmosphere. The expanding channel C has fitted into it a branch pipe D, which is shown bent upwards and terminated in a cylindrical jet nozzle D^1. This branch pipe is led outwards and connected to the furnace or waste heated gases flue from the boiler furnace at any convenient point for the induction of the heated gases from the furnace with the expanding channel C. The expanding channel C is further provided with an annular condensed water trap C^1, from which the water as it is trapped is carried away by the branch pipe C^2 which being in a hot state is advantageously available for being carried away to feed the steam boiler or generator. The action of the apparatus is as follows :—On steam from an engine being passed through the branch pipe A and through the annular nozzle A^1, which may at starting be advantageously contracted by the sliding induction pipe B being pushed up by the hand lever B^2 so as to make the issuing jet of steam from the annular jet nozzle A^1 issue with considerable force until the air current is started rightly, causing thereby at first a little back pressure on the piston of the engine, but as soon as the current is started the sliding piece B is drawn down to give the steam from the engine free escape at the annular nozzle A^1; the cold air being induced in through the pipe B ascends up through the expanding channel C in swift motion, and as it passes the annular jet nozzle A^1, together with its motion and refrigerating action, causes a partial vacuum in the exhaust pipe A and on the piston of the engine, and thereby to some extent utilize the heat from the waste steam. The exhausting action of the expanding channel C can, when convenient, be increased by a pipe D being led to the funnel or flue of the boiler, and terminated in a jet nozzle D^1 in the expanding channel C. The heated gases being thereby induced into to the heated air and steam, and being of a higher temperature than the steam and air in the channel C, further expands it, and increases the draught and consequent exhausting action, the area at the top end of the expanding channel C should be of such a proportion as to cause the mixed steam and air to escape at a slow motion or with little force. In this arrangement of air exhausting channel a large proportion of the steam is not condensed into water, but escapes mixed with the air. The water from condensation in the channel C adhering to the surface of the channel is in its descent trapped by the annular trap C^1, and conveyed away by the branch pipe C^2; the course of the currents is as indicated by the coloured arrows.

Figure 2 is a sectional elevation, and Figure 3 a plan, of an expanding channel and air jet steam condenser for piston steam engines. The expanding channel C being shown in section in Figure 3, through the line 1—1 in Figure 2, this modification of a steam exhauster or condenser is adapted to give a more perfect vacuum and more effective condensation than that described in connection with Figure 1, the air requiring a forcing pump or other forcing apparatus to give intensity to the jet or current, and the heat abstracted by the air from the steam is utilized by leading the air or exhaust current away to the fire-grate of the steam generating furnace to support the combustion of the fuel. The exhaust pipe or port of the steam engine is connected to the branch pipe A, which admits the steam to the condensing chamber A^2, and the cold air pipe B, which is carried up through the condensing chamber A^2, and terminates in a cylindrical jet nozzle B^1 opposite the induction end C^3 of the expanding channel C, is connected to an air forcing pump, which causes the air to flow through it, and issue from the jet nozzle B^1 at a high speed and pressure; the expanding channel C may be, as explained, led to the boiler furnace to support the combustion of the fuel. The cold air rushing across the space in the condensing chamber A^2, between the nozzle B^1 and the throat of the inducing pipe C^3 of the expanding pipe C, has a refrigerating effect, and condenses or partially condenses the steam, giving to the cold vapour as it approaches the jet an eddying motion, and causes the water of condensation from the condensed steam to pass over the curved surface A^4, and drop from the depending edge A^5, as indicated by the arrows. The condensed water is withdrawn by the boiler feed pump through the branch pipe A^3; the course of the currents being as indicated by coloured arrows.

Figure 4 is an elevation, and Figure 5 a plan of another form of air jet steam condenser, having an initial forced air jet, drawing or inducing in another at the pressure of the atmosphere to condense the steam, which arrangement admits of the air pumps or other air-forcing apparatus being much smaller compared with those required for working the modification just described. The branch pipe is connected to the exhaust pipe or port of a steam engine cylinder, admitting the steam to the condensing chamber A^2, and the branch pipe B is connected to the forcing or discharging pipe of an air pump, forcing in at a pressure of about twenty lbs. to the square inch section, and into the chamber B^3

from thence it passes through the branch connection B^4, and issues from the annular jet nozzle B^1. This annular jet nozzle B^1 is set so as to give only sufficient area calculated to the volume of air discharged through it by the pump to give the requisite pressure, force, or speed of air jet, the intermediate chamber B^3 acting as a reservoir to compensate for and cause the intermediate discharge of a reciprocating pump to flow through the nozzle B^1 in an equable jet of air or nearly so. The jet of air from the nozzle B^1 thence flows up through the short narrow annular space C^5 formed between the inner surface of the expanding pipe C and the outer surface of the short truncated conical inner expanding pipe piece C^4, and thence issuing into the main expanding pipe C. This annular air jet being made to issue or play as described induces air from the atmosphere up through the central pipe *b* and short pipe C^4 into the main expanding pipe C in great volume, so that there is a great volume of cold air made to play up through the condensing vessel A^2 and exposed to the steam without any intervening plate between the annular jet nozzle B^1 and the induction nozzle C^3 of the short pipe C^4, and rendered capable of preserving its course and motion against the tendency of the vacuum in the condensing vessel A^2 to draw it inwards, and refrigerating the condensing vessel A^2 in its passage, and condensing the steam introduced into it, the whole large volume of the air passing up into the expanding pipe C being protected from being drawn in by the vacuum or partial vacuum thus formed in the vessel A^2 by the thin annular stream or jet of air issuing from the annular jet nozzle B^1. The portion of the water from condensation that passes up through the annular space C^5 along with the high pressed stream of air is trapped by the annular trap C^1, and led off this the branch pipe C^2, the condensed water from refrigeration in the condensing vessel A^2 being drawn or led away through the branch pipe A^3 by a pump or injector to feed the boiler. The heated air passing up through the expanding pipe C may be utilized by being led to supply the boiler furnace, or may be with a more contracted channel or pipe made to give with advantage motion to a turbine, the course of the currents being all as indicated by the coloured arrows.

Figure 6 is a sectional elevation, and Figure 7 in part a sectional plan of a similar description of condenser to that just described in connection with Figures 4 and 5 to act with an annular jet of forced air and induced central column of air from the atmosphere, but instead of the water

induced up by the forced jet of air being trapped up in the expanding pipe C, a large annular trap C^1 surrounding the condensing vessel A^2 is provided, from which the water escapes by the jet pipe C^2, impelled by the pressure from the inflowing jet of air and water from the action of the air jet from the annular nozzle B^1 in through the annular passage C^5. A cock C^7 is kept sufficiently open to allow the air from the trap vessel C^1 to escape, but to keep up a pressure in it; the water escaping by the jet pipe C^2 to the small ejector C^6 induces out the water from the refrigerating condensing vessel A^2 by the branch pipe A^3, and causes all the condensed water to escape by the throat pipe C^8. The other parts of this condenser being similar to that described in connection with Figures 4 and 5, and the same reference letters referring to similar parts, they need not be further described. The course of the currents is as indicated by the coloured arrows.

Figure 8 is a sectional elevation, and Figure 9 a plan, of a similar condenser to that described in connection with Figures 4 and 5, and 6 and 7, but instead of the air current floating upwards, as in these, it is here caused to flow downwards, and the water from condensation by the air jet or current before the nozzle B^1 and form refrigeration, induced down together into a trap chamber C^1 below the condensing chamber A^2. The air that passes down through the annular throat C^5 along with the water into the trap chamber C^1 is carried away by the pipe c into the inner air pipe or chamber C^4, and escaping by the nozzle jet c^1 into the expanding air pipe C with great force, increases the speed of the main refrigerating current; the water from the trap chamber C^1 is led away by the branch pipe C^2. The action and other parts of this condenser being the same as that described in connection with Figures 4 and 5, and 6 and 7, the same letters referring to like parts, they need not be described again further. The course of the currents being as indicated by the coloured arrows. A small water pipe a^5 is introduced into the channel A^2 to assist the condensation.

Figure 10 is a sectional elevation, and Figure 11 an external plan of a somewhat similar condenser to that just described, but instead of high pressed air being passed through the annular jet nozzle B^1 to induce in the large central inducing column of air from the atmosphere a thin annular jet or film of cold water is used, the central column of cold air in swift motion keeping the small quantity of water used sufficiently cool to condense the steam, and the annular film or jet of water in

motion from the jet nozzle B^1 were exposed to the heat and vacuum of the condenser, preventing the air from getting into the condenser, this condenser being as it were a water jet condenser with a core of air to carry off the heat, so that a greatly diminished quantity of water can be used compared with the quantity used by the common form of water condenser, and admits also of the waste heat being utilized in the form of heated air. The branch pipe A is connected to the exhaust pipe or port of a steam engine, and the steam admitted to the refrigerating and condensing chamber A^2, and water is admitted by the branch pipe B to the annular jet nozzle B^1 causing a thin annular jet to flow downwards across the space from the nozzle B^1 to the throat C^3 of the chamber piece C^4, which is open to the condensing vessel A^2 and thereafter descending down through the annular space C^5 into the water trap chamber C^1, and thence flowing out by the branch pipe C^2 the current or flow of the water from the annular jet nozzle B^1 induces a current of air to pass down through the central air pipe *b*, which air current passes down through the centre of the water jet and through the expanding pipe C, conveying away the waste heat from the refrigerating vessel A^2, causing effective condensation and vacuum within it, and thence to the piston of the engine. To increase the speed and cooling action of the central current of air through the air expanding pipe C an annular steam inducing nozzle D with branch pipe D^1 is provided of a similar form to that described in connection with Figure 1 on Sheet 8, and the branch pipe supplied with steam from the boiler; the courses of the currents are as indicated by the coloured arrows.

Figure 12 is a sectional elevation, and Figure 13 an external plan of another form of combined air and water condenser, whereby a cooling current of air is made to cool the water as it is ejected from a water jet condenser, discharging throat pipe or channel, and the swift motion and heat of the water ejected from the throat or nozzle pipe in the form of a thin film or spray induces in a large central cooling current of air, the air thus heated being discharged to the atmosphere or utilized by being led to the boiler furnace, and the water thus cooled to be returned and used over again as the cooling condensing media for the exhaust steam, the external supply of cold water being chiefly such as will make up for the water carried away in heated vapour by the cooling air. The steam exhaust pipe or port of an engine is connected to the branch pipe A, and admits the steam to the chamber A^2, and the small

branch pipe B admits cold water to the annular chamber B^4. The steam issuing through the narrow annular throat C^5 induces in the cold water from the annular chamber B^4 through the annular nozzle B^5, condensing the steam and forming a vacuum in the chamber A^2, and being ejected by the condensing action through the annular throat C^5 with great force in a thin film, and as it ascends with spray up through the inner expanding pipe C^6, and thereafter projected against the inner surface of the main expanding pipe C, its swift motion and heat inducing in the air by the pipe *b*, and ascending up through the throat piece C^4 and inner expanding pipe C^6, and cooling the water in its course, is discharged through the main air expanding pipe C. The water thus cooled adhering to the inner surface of the main cooling channel C falls by its gravity after its force upwards is expended into the water trap C^1, and thence passes into the annular water chamber B^4 through the openings c^2, and is re-ejected by the steam along with the cold water from the pipe B up to the sides of the main channel C to fall down to the trap C^1 again, and thus a returning stream of condensing water is provided. An overflow branch pipe C^8 is provided for conveying away the water to supply the steam generator. Although I have shown these cooling currents of air passing in vertical directions only they may be made to pass in any other direction. The annular form of nozzle also, though obviously the best for these condensed currents of air at different pressures and of water and air combined, a similar combined action can be carried out with a square or any other form of enclosing nozzle, or a flat jet in a U-shaped enclosing channel, or instead of one several jets may be used. The novel and essential improvements in this part of my Invention are the use of simple air jets, or a combination of high and low pressure air jets, or of air and water jets, as described, for utilizing the waste heat from exhaust steam, both for producing a vacuum or partial vacuum in steam-engine cylinders and for heating a current of air to be used for assisting combustion in furnaces or other purpose.

Another mode of carrying out the improvements under this second head of my said Invention consists in mechanism for working the condensers of piston reciprocating steam engines in lieu of the ordinary air pump, and with water only as the condensing and refrigerating media, consisting of a condensing vessel into which the exhaust steam from the engine and cold water are made to enter, by preference in a thin stream

or jet, and in a downward vertical direction, to be regulated by a valve opening inwards, loaded by the tension of a strong spring or other equivalent means, and in the bottom of the condensing vessel and opposite the top valve a corresponding valve opening outwards is placed so that the jet or stream of water passing through the top valve will play down through the bottom one; underneath the condensing vessel a shallow vessel is placed to contain a quantity of water around the foot valve, to act as a water lute to keep it air-tight and to form a convenient means to carry off the condensed and condensing water. A double-acting or forcing pump is provided wrought by the engine and attached by its discharge pipe to the jet valve chest in the condensing vessel, so as to discharge a portion of water through the jet adjustable valve at every stroke of the engine. The current or jet thus made to play through the condensing vessel may also be made to flow through in some degree continuously by having an air vessel placed in the connecting pipe between the pump and condenser.

Figure 14 is a side sectional elevation through the line 1—1 in Figure 15, and Figure 15 is in part an external plan and partially a sectional plan through the line 2—2 in Figure 14, showing a condenser of this description. The branch pipe A is connected to the exhaust port or pipe of a steam engine, and the steam admitted to the condensing chamber A^2, and water from the forcing pump is admitted by the branch pipe B into the upper valve chamber B^1 which has in its under side a wedge-shaped depending cavity B^2 to the one side of which is fitted and hinged a valve piece B^3, which has a lever piece cast on it and is continued back and held close by it by the hinged rod B^4, which passes up through a stuffing box into the water chamber B^1; on this sliding rod B^4 is placed a spiral spring B^5, which is adjustable to any required tension by the adjusting screw and hand wheel B^6, which works through a stuffing box placed in the cover of the water chamber B^1. The end walls or flanges of the wedge-shaped cavity B^2, in which the valve B^3 is hinged partly cut away to show the form of the flap valve B^3, the air flanges being continued back beyond the ends of the valve, so that when it is forced open the only opening formed is a long narrow slit at the under extremity of the wedge-shaped cavity B^2 seen in plan in Figure 15 by the plan of the under and discharge valve cavity C^2 which is the same in form. This under discharge valve C^2 is fitted with a similar valve C^3, having a hinged rod C^4 fitted with a spiral spring C^5, which

is also adjustable to any required tension for keeping the valve C^3 closed by the set screw C^6 in the same way as described for holding in "tension," and for giving opening play to the valve B^3 being preferably air-tight, the discharge water trap chamber C^1 has its outflow or discharge branch pipe C somewhat higher up than the opening of the valve C^3 so as to keep it always water luted should the discharge pipe connected to the branch pipe C be carried downwards from the condenser. To prevent the inward rush or flow of the exhaust steam from the branch pipe A disturbing the flow of the condensing water jet passing down through the condensing chamber A^2 more at one point than another, thin plates *a*, *a*, are placed inside the condensing chamber A^2 surrounding the condensing water jet as shown and interposed between it and the direct play of the steam current from the steam exhaust pipe A, the arrangement of these plates being best seen in plan in Figure 15. They are perforated with small holes in zig-zag positions at all parts except the part opposite the pipe A, and cause the steam to circulate around the inner surface of the condensing chamber and issue into the centre of the chamber A^2 towards the condensing jet and equally all round it. Thus arranged on steam being admitted by the branch pipe A from an engine, and water from reciprocating pump admitted by the branch pipe B, the chamber B^1, the valve B^3 opens at every stroke of the pump, and a broad thin jet of water is projected down through the condensing chamber A^2 and into the wedge-shaped cavity C^2, causing the valve C^3 to open and let it pass into the trap chamber C^1, condensing the steam in the condensing vacuum chamber A^2, and inducing by lateral action along with it the water and air from the condensation of the steam, and by its force after it passes the discharge valve C^3 flows out by the branch discharge pipe C. The course of the currents is as indicated by the black and coloured arrows. In this part of my Invention the induction valve B^3 and discharge valve C^3 may be of india-rubber, such as known as Prideaux valve or any other convenient form, and the condensing jet may be cylindrical or of any other section instead of the thin flat stream used in the modification.

The essential improvement of this part of my Invention is the use of a self-opening and closing induction valve for the injection water, opening into the condensing chamber intermittently or with a pulsating action by the force of water from a reciprocating pump, and provided also with a self-opening and closing discharge valve which opens with

the impact of the water jet projected against it, the condensing water jet inducing the water and air out of the condensing channel by lateral action and without the use of an air pump, being a convenient modification of what is known as a "blow through condenser" for being wrought by the ordinary double-action water lifting pump by a steam engine.

Another improved mode, means, and apparatus for the condensation of the exhaust steam from steam engines for causing an effective vacuum on the exhaust side of the pistons, and for discharging the condensing water from condensation consists in using and injecting salt or impure water for refrigerating and condensing and of retaining a great part of the water from the condensation of the steam or vapour, free or nearly free from salt or other impurities to serve for the boilers of marine or other engines in lieu of surface condensers. This result can with slight modification be effected by a condenser similar to the one just described by having a wall piece or guard formed in the bottom of the condensing vessel above the discharge valve, around the course of the injected stream of salt or impure condensing water, and rising up above the bottom of the condensing vessel to about one-fourth part of its height, this part of the condensing vessel to form a trap reservoir for the water from condensation of the steam or vapour as it falls down from the refrigerating effect of the cold water admitted into the condensing vessel as in a vacuum or partial vacuum cold water in process of being heated radiates cold vapour from its surface. Steam when being admitted and advancing to the water under this condition must be condensed at some distance from the cold water surface; the stream or jet of cold water passing down through the condensing vessel in swift motion projects from its surface cold vapour in an outward and downward direction, giving to the vapour in process of condensation a downward eddying motion, and the water from condensation and vapour from the cold water falling down will be trapped and collected in the trap chamber formed in the bottom of the condensing vessel to be exhausted out by the feed pump of the boilers.

Figure 16 is sectional elevation, and Figure 17 a plan of a condenser arranged to act on this simple water jet refrigerating principle, in which there is no lateral exhausting action by the condensing water on the water or air from the condensed steam. The form of this condenser so far as the admission of the steam and passage of the condensing water

through the condensers is concerned is similar to that described in connection with Figures 14 and 15, and the same letters of reference referring to like parts, and need not again be described. For effecting the particular action described, a wall piece A^3 is fitted to the bottom and inner surface of the condensing vessel A^2, and surrounds the condensing water jet and discharge valve cavity C^2, forming thereby in the bottom of the condensing vessel the water trap chamber A^4, which is provided with a small branch pipe D for the water and air from condensation being exhausted out by the boiler feed pump. To further facilitate the refrigerating action of the downward current of condensing water, and prevent the condensed water getting in amongst the condensing water, a series of thin guiding plates or "louver boards" a^1, a^1, a^1, are made to surround the stream or jet of condensing water, and cause the cold vapour arising from the surface of the water to pass out between the spaces between them, to meet the steam as indicated by the small blue arrows. The action of this condenser is otherwise the same as that described in connection with Figures 14 and 15, and by it, though salt or impure water is used for refrigerating and condensing, a supply of clean fresh water is obtained from the branch pipe D for the boiler or boilers. The course of the currents are all as indicated by the black and coloured arrows. Various arrangements can be made of this mode and means of condensation, and the jet or jets of condensing water instead of passing downwards may be passed in any direction or over curved plates, on the top side of the condensing vessel, in various ways to facilitate the condensation and deposition of the condensed pure water from the impure condensing water.

Figure 18 is a sectional elevation through the line 1, 1, in Figure 19, and Figure 19 is in part a sectional plan through the line 2, 2, in Figure 18. In this modification of refrigerating and separating condensed water condenser there are no inlet or outlet valves used to or from the condensing chamber, the jets of condensing water being so regulated or proportioned as to play through the condensing chamber, and into and fill a throat pipe set opposite to it, and by its motion and filling the discharge throat keep the condensing vessel air-tight. The steam branch connection A is connected to the exhaust pipe or port of a steam engine, which admits the steam into the condensing vacuum chamber A^2, and the condensing water is admitted by the branch pipe B, from a head or pressure into the water chamber B^1; the bottom plate of the chamber B^1

above the condensing chamber A^2 is shown fitted with nine small cylindrical jet nozzle pieces B^2, B^2, B^2, their nozzles B^3, B^3, B^3, projecting into the condensing chamber A^2, their number and positions being shown in plan by Figure 19. In the bottom of the condensing chamber and opposite these jet nozzles are placed a corresponding number of trumpet-shaped discharging throat channels C^3, C^3, slightly bell mouthed but narrow, and of such a diameter at the throat orifices C^2, C^2, C^2, as to admit of the water jet passing from the jet nozzles B^3 to fill them. These throat channels C^3 open into the water trap chamber C^1, which chamber is provided with a branch pipe connection C for conveying away the condensing water, and the condensing chamber A^2, or the portion of this chamber A^4 which forms the fresh water trap is provided with a branch pipe connection D, for being connected to the boiler feed pump for conveying away the fresh water from the condensation of the steam. The condensing chamber A^2 is also provided with perforated wall plates *a*, *a*, *a*, to keep the rush of steam from the engine through the branch pipe A from disturbing the course of the water jet, as explained in connection with Figures 14 and 15. Thus arranged and steam entered into the refrigerating chamber A^2, and water admitted through the branch pipe B into the water chamber B^1, the water flows through the jet nozzles B^3 down through the condensing chamber A^2, refrigerating and causing the steam to condense and gravitate in the state of water to the bottom of the condensing chamber, and into the trap chamber A^4 formed in it by the throat pipes C^3, C^3, C^3, the condensing water passing down through the throat channels C^3, C^3, C^3, into the trap chamber C^1, and discharged by the force of the jets by the waste water branch pipe C, and the fresh water from the condensation of the steam exhausted out by the boiler feed pump from the trap chamber A^2 by the branch pipe connection D.

Figure 20 is a sectional elevation through the line 1—1 in Figure 21, and Figure 21 is in part a sectional plan through the line 2—2 in Figure 20, of a similar condenser to that described, but instead of the condensing water jets being made to play through the condenser vertically they are made to play across and through the condensing chamber A^2 horizontally, and the water chamber and water traps somewhat differently arranged, there is otherwise no substantial difference between this condenser and the one just described, and as the same letters of reference refer to the same parts in each modification it will not require to be

again further explained; the course of the currents is as indicated by the black and coloured arrows.

Figure 22 is a sectional elevation through the line 1—1 in Figure 23, and Figure 23 is in part an external plan and in part a sectional plan through the line 2—2 in Figure 22, of a similar condenser to that described in connection with Figures 18 and 19, but having the jet discharging throat pieces C^3, C^3, C^3, somewhat differently arranged and each mounted with a series of thin conical guiding plates a^1, a^1, a^1, on the "louver board" principle for giving the motion of the cold vapour arising from the surface of the water jets a downward direction, as explained in connection with Figures 16 and 17. Otherwise this condenser is substantially the same as that described in connection with Figures 18 and 19, and the same letters of reference referring to like parts it does not require other description; the course of the currents being as indicated by the black and coloured arrows.

Figure 24 is a sectional elevation through the line 1—1 in Figure 25, and Figure 25 is in part an external plan and in part a sectional plan through the line 2—2 in Figure 24 of a similar condenser to that described in connection with Figures 18 and 19, but having the branch pipe to which is connected the steam exhaust port or pipe of the engine, formed to pass down through the top condensing water chamber B^1, and the steam branch pipe A narrowed into a cylindrical jet nozzle A^1, where it enters into the refrigerating vacuum chamber A^2, the water from condensation passing down through a throat pipe A^5 placed in line with and opposite to the steam branch pipe A conveying the condensed water into the fresh or pure water trap chamber A^4, which has formed in it the branch pipe D, which is connected to the feed pump or other water feed apparatus for the boilers; the condensing water entering by the branch pipe B into the chamber B^1, and passing down through the jet nozzle B^2 and the condensing chamber A^2, and through the throat pipe C^3 into the condensing water trap C^1 escapes by the branch pipe C. The same letters refer to the same parts as in connection with Figures 18 and 19, and the course of the currents are as indicated by the black and coloured arrows.

Figure 26 is a sectional elevation through the line 1—1 in Figure 27, and Figure 27 is in part an external plan, and in part a sectional plan through the line 2—2 in Figure 26. The condensing water in this condenser is entered under the bottom side of the condensing

chamber A^2 through the branch pipe B into the chamber B^1 and flows upwards through the nozzle pieces B^2, condensing chamber A^2, and throat pipes C^3, C^3, into the condensing water trap chamber C^1, and thence escaping by the branch pipe C. The steam being admitted, as in the modification of condenser described in connection with Figures 24 and 25, by the branch pipe A and through the jet nozzle A^1 in a reverse direction to the condensing jets, the fresh water from condensation passing down through the throat pipe A^5 and out by the branch pipe D to be led to the boilers. In this modification there are 16 condensing jet nozzles employed, and the same letters of reference refer to like parts as in Figures 24 and 25 as in the other modifications, the course of the currents is as indicated by the black and coloured arrows.

Figure 28 is a side sectional elevation, and in part a sectional elevation through the line 1—1 in Figure 28 of a refrigerating water jet condenser, in which the condensing water jet is made to pass through the condensing chamber over a curved plate, or one-sided duct or channel, instead of a straight jet or jets free on all sides, as in the other modifications shown on this sheet; otherwise there is no substantial difference in this modification from these, and the same letters of reference refer to like parts in each. Steam is admitted by the branch A into the refrigerating chamber A^2, and the condensing water is admitted by the branch pipe B into the chamber B^1 and issues into the condensing chamber by the long narrow jet nozzle B^3, and thence passing over the curved top plate of the condensing chamber A^2, as indicated by the black arrows, enters the long narrow throat C^3, and passing through its channel enters the condensing water trap C^1, and escapes by the branch pipe C. Thin transverse guiding plates or "louver boards" a^1 are fitted under the course of the curved stream or jet of condensing water to direct inwards the cold vapour arising from the surface, in a similar way as described in connection with Figures 16 and 17. The condensed fresh water from the condensed steam is led off by the branch pipe D, the course of the currents being as indicated by the black and coloured arrows.

Figure 30 is a sectional elevation of a refrigerating water jet condenser cylindrical in form, all except the branch pipes, and therefore a plan is not necessary to explain its construction; its mode of action is similar to that described in connection with Figures 18 and 19, but having only one condensing jet nozzle and discharge throat pipe A^3. The condensing

water branch pipe B is connected to an annular injector F, to the annular space of which a small water pipe *b* is connected from a pump or other source of supply at a high pressure to induce in the cold water by the pipe B, and to give where required to the outer ring or part of the jet a higher speed than the central or induced part from the pipe B in the same way as explained in using air currents in connection with Figures 4 to 9, on Sheet 8 of my Drawings, for which effect the jet nozzle B^3 may be formed a little shorter than shown by the Drawing. The condensing water discharge pipe C is here also provided by an inducing or water exhausting steam jet nozzle E, having a steam branch pipe E^1 for connecting to the boiler, the same letters of reference refer to the same or like parts as in Figures 18 and 19, and the action is the same, and need not be described. The course of the currents is as indicated by the black and coloured arrows.

Figure 31 is a sectional elevation of a condenser similar to that described in connection with Figure 30, but in this example the branch pipe *b* of the annular injector F is connected to the steam boiler used for starting the water current or jet through the pipe B. The branch discharge pipe C for the condensing is also provided with a hinged valve and chest C, such as required when using a condenser of this description for marine engines, the additional appliances as described in connection with Figures 30 and 31 being when required applicable to the other modifications of condensers described in this Sheet of my Drawings. The essential improvements or new features of this part of my said Invention (Figures 16 to 31) are the use of a jets or jets of cold water to refrigerate and condense the steam so as to keep the water of condensation from the steam separate, or in part separate from the condensing water, and the mechanism and modes for effecting this action, substantially as described for producing a vacuum or partial vacuum to actuate steam engines, and for obtaining pure water for the boiler.

Another improvement under the second head of this my said Invention consists in a mode and mechanism for applying motive power, such as herein-before described under the first and second heads of my Invention, for the purpose of propelling ships or vessels, and for locomotives on land, chiefly for lightness and simplicity and for the attainment of higher speed than has been heretofore reached, particularly for water conveyance, where higher speeds are still much wanted for passenger traffic. The locomotive engine for railway carriages is still a very

complicated, cumberous, and expensive machine, and is itself generally the greater part of the weight it has got to drag along the rails in an ordinary passenger train, and its great unweildy weight necessitates, particularly for passenger traffic proportionate weight and strength in the railway rolling stock to withstand the jolts and concussions it is necessarily subjected to, as also proportionate great strength, expense, and great tear and wear in the roadway. For passenger traffic by water carriage there is not much hope of attaining much higher speeds than is already obtained with any reasonable expenditure of power without having the vessels built very light, and for a light draught of water with also some contrivance to relieve to some extent the bottom of the vessel from the great friction incurred in a considerable surface passing over water at a high speed. The means of propulsion I employ is the reaction of jets of steam and air and also heated gases issuing out into the open atmosphere, the currents so well mixed with the cold air before they escape into the atmosphere as to be in large volume and at no greater speed than is necessary for economical propulsion of the mass to be propelled. In the generation and management of these currents I also employ an advancing, exhausting, or suction action in combination with the receding reacting action of the issuing currents, the mechanism for producing these being similar to that described in the first and second parts of this Invention, and particularly with reference to Figures 36 and 43, on Sheet 6 of my Drawings. Of late I have had considerable experience in the useful application of currents of steam and air generated in this way, and what may seem chimerical to engineers without knowledge or experience of these things is nevertheless a useful mechanical agent for effecting many useful ends.

On Sheet 10 of my Drawings Figure 1 is a longitudinal elevation, in section for the most part; Figure 2, an external or deck plan; Figure 3, an external elevation of the "bows;" Figure 4, an external elevation of the stern; Figure 5, a cross section through the line 1—1 in Figure 1, and Figure 6, a cross section through the line 2—2 in Figure 1 of a vessel built of steel plates $\frac{3}{16}$ths of an inch thick, with proportionately light frames, but having several bulkheads, and all to give the structure sufficient strength for river traffic; all also of a weight to draw the depth of water indicated by the Drawings. I do not show the structional details of the hull, but only or mainly those that are necessary to show the essential parts of this system of propulsion. The yellow coloured

space in the centre of the hull longitudinally indicating mainly the propelling current of air and gases, the spaces H, H, indicating the cabin and deck, J forming the accommodation for passengers. The steam boilers I and I^1 are of the locomotive form, but any form that will give great "steaming" power with little weight being suitable; from these the steam pipe A, A, A, conveys the steam to the six annular steam jet nozzles A^1, A^1, A^1, A^1, A^1, A^1, which induce in cold air from the "bows" of the vessel through a corresponding number of channels A^{11}, A^{11}, A^{11}, A^{11}, A^{11}, A^{11}, extending forward from the nozzles A^1 in a round form, but assuming, as shown, a square form, as seen in Figure 3, and larger in area when they reach the "bows." A corresponding number of jet pipes A^2, A^2, A^2, are shown connected to the nozzles A^1, which have formed in them the annular inducing ports a^1, a^1, a^1, a^1, a^1, a^1, for inducing in the heated gases from the furnace. These annular steam jet nozzles A^1, jet pipes A^2, and inducing jet nozzles a^1, are the same as those described in connection with Figures 36 and 43 on Sheet 6 of my Drawings; Figure 43 showing the same arrangements as here used in all its parts. The funnel pipes a, a, a, convey the waste gases to these inducing nozzles a^1 by branch pipes a^{11} to each, as shown, and connected to the inducing nozzles a^1, and severally to the trumpet-shaped discharge pipe F, F, F, which open out and discharge the currents of steam, air, and gases firstly into the concave space F^1, F^1, F^1, seen in Figure 5, and thence into the long arched space F^3 extending underneath the deck and cabin all the length of the vessel. To give the current thus discharged volume and prevent it getting out to the main channel F at two high a force and temperature, an oblong space B all the breadth or beam of the vessel, and extending from the "bows" underneath the channels A^{11}, conveys air into the space F^1 after the currents receive the waste heated gases; the current also being there induced in by the discharge from the trumpet pipes F, and this out current issuing from the concave channel F, as it flows out into the space F^1, also induces in the air from the bows underneath the plate C^1, C^2, so that on all of the area of the bows of the vessel there is an exhausting or suction action, and all combining to force the current through the propelling channel F^3, as indicated by the arrows, and discharge it at the stern, thereby propelling forward the vessel as described. A current of air generated in this way, and to a pressure of about half a pound to the square inch, has also when so forced into the space below the vessel a bouying-up tendency, and in the example shown, so great at their pressure to

bouy-up about one-half the weight of the vessel, and when in motion proportionally lessens the draught, and so far relieves the hull from the friction of the water. Instead of the square form of vessel shown by these Drawings the hull may be formed of the section indicated by the dotted lines K in Figure 5, which admits of greater strength with the same materials than the square form; the form or section being susceptible of many modifications, the square form as shown, however, giving least resistance to the motion of the vessel. The "bows" of the vessel, as indicated by Figure 3, present only sharp edges to the water and air, and the stern, as indicated by Figure 4, also sharp edges or nearly so, so as to admit of the volume of propelled air to be as large as practicable when it issues from the stern. At each keelson L a rudder M is fitted, which are arranged to be wrought, coupled together by one tiller O, or other steering gear.

Figure 7 is an external longitudinal elevation, and Figure 8, a deck plan of a vessel of the common form, with two propelling boilers and apparatus of a similar description. In this example the propelling current is conveyed from the annular steam jet nozzle A to the stern of the vessel in a propelling channel F^3 on deck, and is of a square form composed on the top and sides of a series of thin plates f^3, f^3, f^3, which on the top side are set level to the water line of the vessel, and on the sides parallel with the midship line of the vessel, exposing therefore to a direct head wind only the sharp edges of these plates, and necessarily leaving a space at the edge of each, which, as shown, are caused to overlap a few inches like "louver boards," the spaces or openings thus formed inducing in cold air by the force of the current, as indicated by the small yellow arrows, and thereby increasing the volume of the propelling current issuing from the expanding propelling channel F^3 at the stern of the vessel. Cold air is induced in from the bows, in this example, to the steam annular jet nozzle A^1 by the channel A^{11}, and to current F^1 by the channel B, otherwise the construction is the same as described in connection with Figures 1, 2, 3, 4, 5, and 6, and the same letters referring to like parts other description is not required. In this example, however, provision is made for reversing the motion of the vessel by reversing the motion of the current by a double or reversing steam annular jet nozzle, as shown in section Figure 9. This nozzle is the same in form as that described in connection with Figure 35 on Sheet 6 of my Drawings, and does not require other description than

there given to make it understood. By this nozzle the cold air is induced in by the channel F^3 and forced out by the channel A^{11}, which propels the vessel in the opposite direction or makes more astern.

Figure 10 is a side longitudinal elevation of a vessel propelled in a similar way to that described in connection with Figures 7 and 8, but instead of an ordinary steam boiler I use a jet current vapour generator for generating the actuating steam or vapour, as described in the first section of this said Invention in connection with Sheets 1, 2, and 3 of my Drawings, and therefore details are unnecessary to be given here, otherwise the arrangements are the same as in Figures 7 and 8, and the same letters referring to like parts, and need not be described.

On Sheet 11 of my Drawings are Drawings of a locomotive engine for railway traffic to be actuated in this way, of which Figure 11 is an external end and smoke box elevation, Figure 12 an external side elevation, Figure 13 an external fire-box end elevation, and Figure 14 an external plan. The boiler I used is a common locomotive boiler, and the framing H, with its axle boxes, axles, and wheels are also of the common form at such parts, and do not therefore require any description. The water tank and coal bunker J is also of the common form, and does not necessarily require any peculiarity for a locomotive of this description from that of an ordinary locomotive engine, although changes both on the framing and other parts, chiefly for the sake of lightness, could advantageously be made. In this description of locomotive dead weight in order to get "bite" on the rails is not necessary, one object sought in its application being that it may "bite" or otherwise injure the rails as little as possible. I use these common forms of parts in use partly that they may be readily understood and partly to show the adaptation of these parts in use for being used for this system of propulsion. A steam pipe A conveys the steam from the steam dome of the boiler I to four annular steam jet nozzles A^1, A^1, A^1, A^1, similar to those described and used in connection with Figures 1, 2, 3, 4, 5, and 6 on Sheet 10 of my Drawings, the steam pipe having branches to each, as shown, the steam being simultaneously admitted and regulated to all of them by a regulating valve wrought by the handle K above the fire-box door, which valve and handle are of the ordinary form used in locomotive engines. Each pair of these nozzles A^1, A^1, on each side of the centre of the boiler are provided with a suction forward

bell mouth piece A^{11} through which cold air is induced with great force by the steam jet, and ejected through each nozzle by a jet pipe F connected to each, the positions and length of which will be best seen in plan in Figure 14. A funnel *a*, seen in Figures 11 and 14, connected to the top of the smoke box, is bent backwards between each pair of the steam jet nozzles A^1, and terminates, as indicated by the dotted lines, at the same point backwards as the four jet pipes F. Two suction air spaces A^{111}, A^{111}, one under each pair of suction bell mouths A^{11}, A^{11}, induce in cold air underneath the jet pipes F, and is induced in by and meets the joint currents from the jet pipes F and funnel *a*, all of which are entered into a large expanding channel F^3, which, as seen in Figure 12, extends backwards beyond the boiler fire-box and to the full length of the carriage, and rests upon the top of the water tank J. This expanding channel F^3, into which the joint currents from the four jet pipes F, funnel *a*, and air passages A^{111} is ejected in large volume at a high temperature and with great force, is composed of a series of thin plates placed level longitudinally on the top side and overlapping each other slightly, but from their general sliding positions allowing a small space or opening between them, as seen in section by the last four plates *b*, *b*, *b*, *b*, above the water tank *j*, seen in Figure 12, so that on the top side of this channel F the advancing motion of the locomotive presents the edges of the thin plate *f*, *f*, *f*, to the air and the spaces intervening between the plates as indicated by the small yellow arrows. The side plates of this propelling channel F^3 are placed parallel with the central line of the locomotive, so that they also present their edges only to the air from the ends of the locomotive. Owing to these being a smaller forward inclination on the sides they are made fewer in number than the top plates to allow ingress space between them for cold air, seen in section in the plan Figure 14, the arrangement for inducing cold air being nevertheless the same as on the top side. Thus arranged, and steam admitted by the steam pipe A, an inward flow of cold air suction or drawing forward action is produced in the bell-mouthed suction air channels A^{11} and A^{111} leading to the annular jet nozzles A^1 and to the inducing ends of the jet pipes F, as indicated by the yellow arrows, inducing in also the waste gases through the funnel *a*, and, as explained, entering the large expanding channel F^3 with great force and at a high temperature, and after entering on its course through the channel F^3 at every successive "louver board" plate the current induces in an additional quantity of cold air, producing

therefrom a corresponding suction or drawing forward action, and increasing the volume of the current, the temperature of the current diminishing with each accession of volume both from quantity and expansion, and is finally expelled in large volume and swift motion at the end of the channel, assisting the forward suction propelling action by a reacting propelling action, and which when the locomotive is in motion at full speed escapes from the propelling channel F^3 with little force.

Figure 15 is a side elevation, Figure 16 a fire-box end elevation, and Figure 17 a plan of a similar locomotive, but having a double annular steam jet nozzle A^1, as explained in connection with Figure 9 on Sheet 10 of my Drawings, for producing reversing action. This difference, and with the suction channel A^{11} made a little longer, being all the difference in this modification from the one just described, and as the same letters refer to like parts, further description is unnecessary. It is also intended to work or actuate locomotive engines of this description with the most suitable modifications of my jet steam or water generators, described under the first head or section of my said Invention. From its lightness as compared with ordinary steam boilers it possesses peculiar advantages for being used for purposes of locomotion in this way, as the removal of dead weight makes this mode of propulsion applicable with more advantage to inclines and light passenger traffic.

Figure 18 is a side elevation, Figure 19 an end elevation, and Figure 20 a plan of a light locomotive with a steam generator I of this description, as described in connection with the first three Sheets of my Drawings, further description being therefore unnecessary here. It is shown combined with passenger compartments on the same frame H and the propelling channel F^3 placed on the top of the passenger compartments L, and in this way a simple and light locomotive carriage can be constructed, the course of the currents and motion of the carriage being as indicated by the arrows, and the main parts being similar to the other modifications described of these locomotive engines, the same letters referring to like parts other description is unnecessary. An element in the calculation in the utilization of heat or force applied mechanically in this way is the consideration that whilst in a common locomotive engine fully one half of the heat or force of the fuel consumed escapes up the funnel in the state of waste heated gases and is quite wasted, by this plan the waste gases along with the steam are all more or

less utilized. The escape of the currents when the locomotive is in full motion will not be materially much more of a nuisance (if any) than that from a common locomotive engine, as the quantity in each case, supposing the power the same, that must escape will be much the same in both machines. The essential improvements of this part of my Invention consist in the application of steam jet nozzles for the induction of cold air and heated gases from the furnace to produce a propelling current as described, having a suction or induction channel "forward" of the steam jet nozzles for cold air and successive induction openings and channels for heated gases after or following the steam jets with annular or otherwise formed steam jet nozzles, also the particular arrangements and use of the similar steam jet nozzle A^1 and the forms of propelling channels described for vessels and for the locomotives as described to actuate or propel in either direction by the combined current of steam, cold air, and gases escaping into the open atmosphere, the currents being generated and made to act in a forward or backward direction.

This said Invention under the third head or section consists in improved mechanism and arrangement of parts of reciprocating piston steam engines or fluid power engines, part of which mechanism and arrangements being also suitable for measuring fluids. One principal improvement under this head or section in its simplest form consists in a cylinder and piston fitted with a strong piston rod continued into a guide for steadying the rod, and the piston made somewhat greater in length than the stroke of the engine and the cylinder made correspondingly in proportion to give room for the piston and end clearances, and fitted with covers and a stuffing box for the piston rod much in the usual way. A strong lateral pin or arm about the same length as the stroke of the engine is fitted into or upon the piston rod and gives or serves out the power of the engine to the crank shaft. In one modification this arm has formed on its end a ball or other spherically formed end, and fitted upon this a correspondingly formed bush which is placed in a hole or slot in a crank or disc which is keyed or formed upon the revolving shaft usually termed the crank shaft of the engine. The inner surface of the crank pin or arm bush is correspondingly spherical and formed in halves to get it on to its seat; its outer surface may be round or square but must have room in the hole or slot in which it is placed for a slight "play" longitudinally in the direction of the length of the crank shaft, the

distance from the centre of this bush to the centre of the crank shaft determining the "throw" of the crank, and as usual double this length the length of the stroke of the engine. The crank and crank shaft thus coupled to the piston rod on the piston being traversed from the end of the cylinder besides longitudinal motion, the arm fixed to the piston rod passing round with the crank bush also imparts to the piston and piston rod a sectional, angular, or sectional twisting or turning reciprocating motion and a corresponding angular turning or twisting motion between the surface of the long piston and the internal surface of the cylinder. This sliding twisting motion of the piston on the surface of the cylinder is made available for opening and closing the induction and eduction steam passages to and from the cylinder; the steam passages being thus formed in the piston and cylinder no steam slide or other regulating valves or motions are required for this form of engine.

On Sheeet 12 of my Drawings, Figure 1 is an external side elevation; Figure 2, a sectional plan of the cylinder and external view of the piston through the steam and exhaust port through the lines 1—1 in Figures 1 and 2; and Figure 4, a longitudinal elevation of the piston through the line 1—1 in Figure 3. In this modification there is one steam induction port formed in the cylinder, and two exhaust ports and two steam passages only formed in the piston, which last condition forms the distinctive features of this modification. Steam is admitted to the cylinder from the boiler by the branch pipe A, the inner end of which A^1, seen in Figure 3, forming the steam induction port of the engine. The piston B when in the position shown by Figures 2, 3, and 4, has its steam passage B^1 opposite the steam port A^1, in which state the steam flows in through the passage B^1 in the piston, as indicated by the blue arrows seen in Figures 2 and 4, the passage being, as shown by Figure 4, when near to the end of the piston diverted inwards to the centre of the piston and out at the end of it to allow space and body of metal around the packing ring B^3, and in which state the motion of the piston is as indicated by the black arrow placed upon it in Figure 2. The exhaust steam from the opposite end of the cylinder at the same instant entering in from the cylinder by the similarly formed passage B^2, as indicated by the blue dart, and escaping through the exhaust port A^2 passes out by the exhaust branch pipe A^5, as indicated by the blue darts as seen by Figure 3. When the piston B in motion, as indicated by the arrow placed upon it,

advances to the end of the cylinder the passage B^1 in the piston gets twisted round by the action of the crank disc arm D and piston rod C until the steam enters in by the port A^1 into the passage in the piston B^2 and the passage in the piston B^1 opens on the exhaust port in the cylinder seen in Figure 3, becoming thereby an exhaust passage for the steam from the other end of the cylinder, and when, by the crank or disc E turning round, the piston gets to the middle stroke or middle of the length of the cylinder the passage B^2 is in the position in which the passage B^1 is shown, and the passage full open upon the exhaust port A^3 in the cylinder, and so on alternately, the passages B^1 and B^2 in the piston becoming alternately a steam induction and eduction passage. In this modification there is no lap or steam cut off obtained to work the steam expansively.

Figure 5 is also a plan of Figure 1; and Figure 6 is an end elevation, the cylinder being shown in section, showing a form of cylinder and piston somewhat differently arranged in the steam ports and passages, but otherwise the same as described in connection with Figures 2, 3, and 4. In this modification there is one steam induction port A^1 into the cylinder as in the modification just described, but instead of two exhaust ports there is only one exhaust port A^2, which arrangement of ports require a pair of steam induction passages B^1 and B^2, and a separate pair of exhaust passages B^3 and B^4. The piston of the piston B in both Figures 5 and 6 is shown as at the end of the stroke, and in Figure 6 the steam port A^1 is shown opening into the steam passage B^2 in the piston, and the exhaust port A^2 in the cylinder is shown opening into the exhaust passage B^3 in the piston. The form of the steam passages in the piston B^1 and B^2 will be seen from Figure 5, which gives an external plan of the piston, each of the passages opening into one end of the cylinder underneath the packing ring B^6 in the same way as shown by Figure 4, and the exhaust passages B^3 and B^4 shown in section in Figure 6, are in plan exactly the same as the steam passages B^1 and B^2, both being arranged to keep the passages full open and with little or no cut-off or lap to the end of the stroke; otherwise the action of steam and exhaust ports as the piston is moved and the twisting action given to the piston and piston rod C by the arm D as the crank or disc E goes round, and the action of the steam and exhaust port therefore is the same as explained in connection with Figures 2, 3, and 4. In the

modification of steam and exhaust ports in the cylinder and in the steam passages in the pistons described in connection with Figures 2, 3, and 4, as also that just described in connection with Figures 5 and 6, there being no lap on the passages in the piston, if the steam be made to enter by the exhaust port it will escape as freely by the steam port, and thereby by simply changing or directing the steam from the boiler to the exhaust port instead of the induction port it will reverse the action of the engine. Figure 1 and 6 show this engine fitted with a common four-way cock A^6 to effect this action, which on the key being turned changes the passages of the steam as explained, will effect this reversing action described. The piston rod C is carried and oscillates in the guide bush bracket C^1 fixed upon the sole plate G, and the working arm D which communicates the power of the engine to the crank or disc E and crank shaft F is cottered into the boss C^2 formed on the piston rod, and on its working, and has formed on it the spherical bush neck D^1, and the crank disc E has the hole or slot E^1 bored in it into which the bush E^2 formed in halves and turned on its outer diameter fits the hole E^1, and turned in its inside to fit the spherical end D^1 of the arm D works the spherical form of the neck D^1 and bush E^2, accommodating itself and working freely in all the positions which the arm assumes in its revolutions round with the crank, a slight traverse being also caused in the bush E^2 in the hole E^1 in the direction of the length of the crank shaft which the bush E^2 is formed to do. The crank shaft is set in the bush bearing bolted to the sole plate of the engine G, and the outer end length set in bush bearing F^3. The crank shaft has keyed on it a fly wheel H, which completes this form of motive-power engine, the arrows only showing the motion of the engine in each modification in one direction, and the blue arrows showing the steam currents, and blue darts the exhaust currents correspondingly.

Figure 7 is an external elevation; Figure 8 a plan showing the steam cylinder in section; Figure 9 showing another and inverted vertical plan of the cylinder; Figure 10, an end elevation showing the cylinder in section through the line 1—1 in Figure 8; and Figure 11, a corresponding inverted sectional elevation through the line 2—2 in Figure 9 of the cylinder and piston of the engine shown in Figure 9, similar to that described in connection with Figures 1, 5, and 6, but arranged to work the steam expansively, this arrangement of ports being

such as affords ready facility to form them to cut off the steam at any desired point of the stroke from about one-tenth of the stroke to any greater fractional part thereof, and having also the driving arm D, bush F^2, and crank disc E somewhat differently formed. The steam in this modification is admitted by the branch pipe A round the passage a^1 to the port A^1 underneath the cylinder, seen in section in Figure 10, and exhausts from the top side of the cylinder by the exhaust port A^2 and exhaust branch pipe A^5, the exhaust port in the cylinder and exhaust passages B^1 and B^2 in the piston bearing on the top side. The form of the exhaust passages B^3 and B^4 are seen in the plan Figure 8 given of the cylinder, which, as described in connection with Figures 1, 5, and 6, are formed the full length of the stroke of the engine, and therefore give for nearly the full stroke a free exhaust for the steam, the inverted sectional plan of the cylinder and external plan of the piston B (Figure 9) showing the length and form of the steam ports longitudinally, and the corresponding inverted sectional elevation showing the ports in the cylinder and passages in the piston in section through the line 2—2 in Figure 9. As it will be seen by Figure 9 the steam passages in the piston are only left open towards the port or ports of the length of the stroke, in this example about one-half the stroke; the steam thereafter in its passage to the cylinder is cut off to this extent, and the steam passage continued underneath the surface of the piston, as indicated by the dotted lines and dotted arrows shown in the port B^1. In this way, as will be readily seen, by shortening the opening or open part of the steam passages B^1 and B^2 in the piston out to the port in the cylinder the steam cut off will be proportionately shortened, so that within about the limits stated any degree of cut-off in the length of the stroke can be effected, shortening the openings in the steam passages B^1 and B^2, as described. The working of the steam ports and steam passages are otherwise the same as described in connection with Figures 1, 2, 3, 4, 5, and 6, and the same letters referring to like parts a further description of this part of this engine is unnecessary; the motion is as indicated by the arrows, the steam currents indicated by the blue arrows, and exhaust steam by the blue darts. The arm D in this example has the spherical end or neck D^1 loose on its end to allow the end play to take place in the parallel rent of the arm D, passing through the spherical end or bush neck D^1, the crank E being provided with a movable cover and bolts E^3 for giving adjustment for wear, and for getting in the spherical piece D^1.

Figure 12 is an external side elevation, and Figure 13 a plan with the cylinder shown in section and showing an external plan of the piston; Figure 14 is an end elevation showing the cylinder with its steam ports and passages in section through the line 1—1 in Figure 13. The form of the steam ports in this engine are entirely similar to those described in connection with Figures 7, 8, 9, 10, and 11, but have got two sets of passages formed in the piston B and in a reverse way to give reversing action. As these parts are the same and the same letters of reference referring to like parts they need not again be described; the ports in the cylinder and passages in the piston shown out of action being left without letters of reference. Those shown in action have the same letters in like parts as in Figures 7, 8, 9, 10, and 11, and the courses of the currents and motion indicated, the same arrows indicating the motion and the blue arrows and darts the motion of the currents of steam. In reversing the currents the cylinder is provided with two slide valves. The slide valve I seen in section in Figure 14 having the steam port A^1 open to the casing, and the slide valve J having the exhaust port A^2 open, giving motion to the engine accordingly. On the handle K being raised and the slide valve I and J moved to the opposite ends of their casings, the other set of ports and passages shown come into action, and the motion of the engine reversed. The other parts of this engine being similar to those already described, and the same letters of reference referring to like parts other description is unnecessary. All of these modifications of engines on this Sheet of my Drawings, by making the ports or piston passages without or with little cut-off of the actuating currents, are suitable for being wrought or actuated by water or other liquids, and it is intended to so apply them.

On Sheet 13 of my Drawings Figure 15 is an external plan, and Figure 16 an external elevation of a combined high and low pressure engine with cylinders, pistons, and all working details constructed in this way, having one cylinder A^{II} actuated by steam from a boiler or steam generator, and the exhaust steam from it conveyed to the induction port of another similar but larger cylinder A^{III}, and the exhaust steam from the larger cylinder A^{III} conveyed to a condenser a^2, forming thereby what is known as a combined high and low pressure engine or a non-condensing and condensing engine combined. The pistons of both cylinders A^{II} and A^{III} are fitted on one piston rod C and

transmit their force through an arm C^1 to the branch E in the same way as described in the various modifications of these engines on Sheet 12 of my Drawings, the twisting or oscillating action thereby communicated to the piston rod C regulating and working the steam induction and eduction ports and passages of both cylinders A^{11} and A^{111} simultaneously, the steam ports and passages in the long pistons being formed the same as described in connection with Figures 7, 8, 9, 10, and 11 on Sheet 12 of my Drawings. The steam pipe from the boiler being connected to the steam branch A formed on the top of the high pressure cylinder A^{11}, and exhausted from it by its under side into the passage G^1 indicated by the dotted lines in the sole plate G, which extends to the induction port on the under side and into the centre of the condensing cylinder A^{111}, the exhaust port of this cylinder and exhaust branch pipe A^5 being on its top side and to which the bent pipe M connects it to the steam branch pipe *a* of the condenser a^2. This condenser is generally similar in its construction to that described in connection with Figures 14 and 15 on Sheet 9 of my Drawings, and the same letters of reference refer to the same parts, only the letters are here given in italics and need not be otherwise described. The condensing water is discharged by the branch pipe *c*; a double acting water pump is shown connected to the condenser by the pipe B for supplying it with water and the same rod that works the pump N is extended and forms the plunger for a feed pump O for the boiler, both being brought from the piston rod of the cylinders C by an arm P having a double jointed box by which it works loosely on the piston rod C and held in its position by the boss of the arm D, and as shown extended and made to embrace the pump rod N^1 on which it is keyed; the same letters refer to like parts in this engine as in Figures 7 and 8 on Sheet 12. This engine with slight modifications may be used as a simple condensing engine by substituting for the high-pressure cylinder A^{11} a guide for the piston rod or a water pump.

Figure 17 is an external elevation, and Figure 18 an external plan of a vertical cylinder engine with an air pump N wrought by the piston rod all fixed on a standard casting G. The form of the cylinder of this engine and all its working parts are similar to those described in connection with Figures 7 and 8 on Sheet 12 of my Drawings, and the same letters of reference referring to like parts. It is further shown having its exhaust port A^5 connected to an air steam condenser a^2

similar to that described in connection with Figures 4 and 5 on Sheet 8 of my Drawings. The same letters refer to like parts on it as on Sheet 8, but are here given in italics, further description here is therefore unnecessary. The motion of the engine is as indicated by the arrow on the fly wheel H, and the course of the steam and air currents are as indicated by the coloured arrows.

Figure 18, A is an external side elevation, and Figure 19, an external plain of a combined steam engine and pump or donkey pump," the steam cylinder A^{11} and all the working parts being similar to that described in connection with Figures 7 and 8, on Sheet 12 of my Drawings, and the same letters of reference referring to the same parts in each. The pump N is also formed with a long piston, and with ports and passages in it similar to that described as being wrought by steam in connection with Figures 1, 5, and 6 on Sheet 12 of my Drawings; the ports and passages being wrought by the same oscillating action of the engine, and set the opposite way from that of the steam cylinder ports and passages in the piston, so as to give a suction or induction action when the steam is forcing in the cylinder A^{11} on the same side of its piston, and thereby cause the water cylinder to act as a double-acting pump, the inlet and outlet being as indicated by the black arrows. This arrangement makes an efficient pump without valves of any kind, and is suitable for both forcing and exhausting purposes for liquids, air, or gases, and forms a very simple gas exhauster for gasworks. Any ordinary form of pump can be and is intended to be used connected to a continuation of the piston rod C of this form of steam engine as a " donkey " pumping engine.

Figure 20 is a front external elevation, Figure 21, a side external elevation, and Figure 22, in part is an external plan, and in part a sectional plan of a pair of these oscillating and reciprocatory cylinders combined, and connected to one crank shaft to act as a meter for measuring liquids. The form of the ports and passages in the pistons used are the same as described in connection with Figures 1, 5, and 6 on Sheet 12 of my Drawings, and the same letters of reference refer to the same parts in these Figures as in this combination, and do not require to be otherwise further described. The water enters by the branch pipe A, and passing through the channels and ports indicated by the arrows passes out by the exhaust pipe A^5. The capacity of the cylinders being made to any desired aliquot part or understood

quantity as indicated by an ordinary liquid index through the small wheel P on the crank shaft gearing into the wheel Q, which has formed on its spindle the small worm R gearing with the worm wheel S, to which an ordinary index can be geared, and forming thereby a complete water meter. Two cylinders can be coupled in various ways as a coupled engine, and this also illustrates one way of doing so. The essential improvements or features of novelty of this part of my Invention consist in the method of actuating the crank shaft by the arm for giving an oscillating action to a long piston in which are formed in part the steam passages to and from the steam or fluid room or space in the cylinder, instead of the ordinary slide valve, and all in the new or improved manner, and for the uses and purposes substantially as described.

Another improvement under this third head is for the regulating and governing the speed of fluid motive-power engines, and consists in the use of various equivalent forms of segmental turbine-formed wheels or discs, or pendulous valve pieces, with a slanting opening or openings of a "louver board" shape, or series of small vanes, on which the passing current of steam or other fluid is caused to impinge, and balanced by a spring or pendulous acting weighted lever connected to actuate or shut off a throttling valve or disc, so arranged that when the engine "runs" away at a speed beyond what is desired, and the steam or actuating fluid correspondingly increasing in speed or force, this excess of force will act on the vanes or "louver board" pieces, and so far overcome the weight of the balancing spring or pendulum as to close or throttle the passage of the fluid, so as to keep the speed of the engine at or approximately at the speed or motion required, and that without any mechanical gear connected to the moving parts of the engine. The centre of gravity or vibration of the balance weight or pendulum may be made to vary by the pressure of fluid or steam, and thereby give more delicate regulating action. This apparatus acts both as a governor and as a throttle valve suitable for marine and other engines, and the position which the pendulous balance weight assumes will approximately indicate the quantity of fluid or steam passing through it.

Figure 23 is a side elevation, Figure 24 a sectional elevation, and Figure 25, a sectional plan of one modification of a motive-power engine governor of this description composed of a circular case A^2 with a steam inlet branch pipe A and an outlet branch A^5, these branches being

about the same sectional area as the steam engine steam pipe to which they are to be applied, and are placed in the steam pipe as part of the pipe connecting the steam boiler to the engine. The case A^2 is accurately turned out, having a bush step A^1 bored in its bottom side, and faced and fitted with a cover A^{11} on its other side having a stuffing box and guard A^3 for the spindle of the turbine regulator seen in section in Figure 25, the case A^2 thus formed being a short cylinder, the circumferential surface of which is bored out as described. It is not necessary that the bottom and inner surface of the cover be faced, but only the washer parts of the footstep A^1 and the inside washer around the bottom of the stuffing box A^3. A brass segmental valve piece B by preference cast in one piece, and with two pairs of arms B^1 and B^2 having a central spindle piece turned to fit the step bush A^1 and the stuffing box A^3 freely, and extending beyond it for the attachment of the pendulous lever C on which the weight C^1 seen in Figure 23 is fixed. The arm and segmental side pieces B^1, B^1, of the turbine valve piece B have cast between them a series of small vanes *b*, *b*, *b*, seen in section in Figure 24, and the arms B^2, B^2, have formed on their extremities the circumferential valve piece B^4, the whole being "turned up" to fit the case and to oscillate in it freely, accurate fitting not being necessary. Thus arranged, and on steam being made to enter by the branch pipe A and pass out by the branch A^5 so long as the speed of current passing through the case, as indicated by the arrows, is of such a force as the weight C^1 on the pendulum C may be adjusted to, it will remain near a perpendicular position, as shown in Figure 23, there is no closing motion of the turbine wheel B, but on the speed of the engine increasing and the current proportionally increased, the current impinges with greater force against the obliquely set vanes *b*, *b*, *b*, causing the turbine valve B to cut off the space at B^4, and to turn round, as indicated by the dotted lines b^4 seen in Figure 24, and narrow or close the branch pipe A^5, the pendulum C and weight C^1 assuming the position (or approximately so) shown by the dotted lines C^1 seen in Figure 23, and in this way regulate the speed of the engine. To prevent the pendulum C getting swung round too far, a pin D is fixed in the case cover A^{11}, on which it is arrested when the branch A^5 is closed by the segmental valve piece B^4.

Figure 26 is a similar arrangement of governor to that described in connection with Figures 23, 24, and 25, but instead of the weighted pendulum the lever C is kept in tension against the closing action of the steam current by a "Salters" balance E, this or any other good

description of spring balance being the most suitable for marine and other purposes where the position in which the engines are placed may be unsteady.

For more delicate regulating effect Figure 27 is an external front elevation, and Figure 28, a transverse sectional elevation of a similar governor to that just described in connection with Figures 23, 24, and 25. In this arrangement the pendulum C is formed of the section shown by Figure 28, being a closed vessel with only a small opening from it through the spindle B^3 of the turbine valve B into the case A^2 from the central chamber C^3 in the pendulum as indicated in section in Figure 28. On this closed pendulum C being first filled with air and then with water until the central cavity C^3 is full, the air will collect in the manner of an air vessel on the top of the annular cavity C^1 and remain in the state as shown in Figure 28, but on pressure being given to the column of water C^3 from the motive fluid inside the case A^2 through the small hole in the centre of the spindle B^3 of the turbine valve B, as shown in the sectional view Figure 28, the central column of water C^3 gets depressed and the water caused to rise in the annular chamber C^1, C^1, correspondingly, thereby extending down the centre of vibration of the pendulum C, every increment of increase of pressure causing the water to rise further in the annular chamber C^1, the limit to the extension downwards of the centre of gravity of the mass of water in the pendulum being when the water line in the chambers C^3, C^1, are on one level. In this way by the pressure of the steam increasing the lenght of the pendulum is proportionally increased.

Figure 29 is a side sectional elevation, Figure 30 a sectional end elevation through the line 1—1 in Figure 29, and Figure 31 an external elevation of a modification arranged for the current to actuate the segmental turbine valve B in line with its axis, instead of crossways as in the last example, but having also the same arrangement of a series of vanes *b*, *b*, *b*, and a closing or throttling valve piece B^4 on the opposite face and branch of the case A^2. The same letters of reference refer to like parts in this modification, and its action is similar to that described in connection with Figures 23, 24, and 25, and does not require therefore to be re-described. The essential improvement of this part of my Invention is the use of oblique vanes in connection with a motive current, arranged to work a throttling valve by the impingement of the current on a vane or vanes, as described.

The last improvement under this third head or section of my said Invention consists in the transmission of motion at high speeds for the motive-power engines herein-before described, by employing on the engine crank shaft or first revolving shaft a wheel with a broad rim, having a seat or channel cut in it, in which is placed a leather belt in one or more breadths, having the one end passed down through a cross slot in the rim of the wheel, and secured by a cotter or other means, and when passed round the rim and down through the same cross slot as the other end is fastened in and brought down and round upon a tightening roller placed in the arm or central part of the wheel, so as to tighten up the belt as it extends in the direction of the driving motion, which is caused to have a "tauting" effect on the belt, the driven wheel to be a plain surface wheel and formed of any suitable metal. In large wheels of this description the best arrangement is to have the belt put on in two pieces or breadths, and the cross fastening slot of each belt only formed half the breadth of the wheel in each, at different places, so as to have the joints at different positions.

Figure 32 is a side elevation, partly in section, Figure 33 an edge view, and Figure 34 a plan, partly in section, of a pair of wheels *a*, *b*, formed as described in the main features, the centre arms and rim being for the most part similar to an ordinary frictional wheel, the arrangement being in this example for placing on the belt in two breadths. A seat or channel A is cut in the rim nearly at full breadth to about the same depth as the thickness of the belt, leaving only the small ledges A^1, A^2, at the sides with a slot A^3 half the breadth of the wheel, and in width sufficient to take in both ends of the covering belt *c*, one end being first put in and fastened by a cotter A^4; the other end is passed round the wheel and down through the same cross slot A^3 as the other end, and wound upon a tightening bolt B, which works in holes *a*, *a*, formed in the double flanges in the arm of the wheel *a*, and in this way the belt is drawn on tight on the rim. The other half-breadth belt c^1 is similarly fixed and tightened up by the tightening bolt B^1, and both fixed so that the motion of the wheel *a* in transmitting power from the frictional contact of the belt will tend to draw the slack into the end to be wound on the tightening belts B and B^1, the slack being wound up from time to time on the bolts as the driving action causes the belt to become slack, the form of the rim of the wheel with the covering belts put on being seen in Figure 1. Formed in this way

these wheels transmit the power of the engines with little friction on the axis bearing, and with very little noise.

The new or improved motive-power engines herein described are applicable to and are intended to be used for the transmission of motive power for the various purposes for which stationary, marine, and other ordinary motive engines have been used heretofore.

Having thus particularly described the nature of my said Invention, and the manner in which the same is or may be performed or carried into effect, I wish it to be understood that I do not confine or restrict myself to the precise details or arrangements which I have had occasion to describe and delineate, as many variations may be made therefrom without departing from the main or essential features thereof; neither, on the other hand, do I claim having invented many of the details of mechanical constructions and motions which I have had occasion to describe for the purpose of making my said Invention properly understood by themselves, as many of these have heretofore been used in various forms of ordinary motive-power engines and machines, except in so far as these are combined with, form part of, or constitute any of the several improvements which I believe to be new and original, and therefore claim as the Invention secured to me by the herein-before in part recited Letters Patent, namely, the construction and arrangement of the parts of motive-power engines and fluid-measuring machines and their uses, and modes and means of producing and using the motive fluids for and through these engines and parts thereof, all substantially in the new or improved manner herein-before described and distinguished as forming this my said Invention, or any mere modification thereof.

In witness whereof, I, the said James Robertson, have hereunto set my hand and seal, this Twelfth day of April, in the year of our Lord One thousand eight hundred and sixty-nine.

JAMES ROBERTSON. (L.S.)

Witness,

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